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A STUDY OF CLIMATIC EFFECTS ON ROOF SYSTEMS AT CAPE HATTERAS, N--ETC(U)
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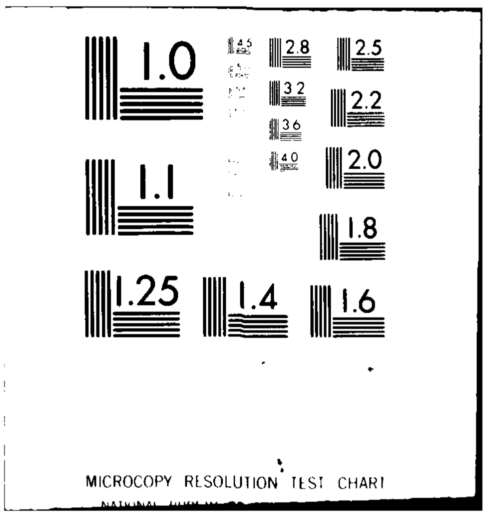
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TECHNICAL REPORT M-285
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Improved Roofing Materials & Systems

A STUDY OF CLIMATIC EFFECTS ON ROOF SYSTEMS AT CAPE HATTERAS, NORTH CAROLINA

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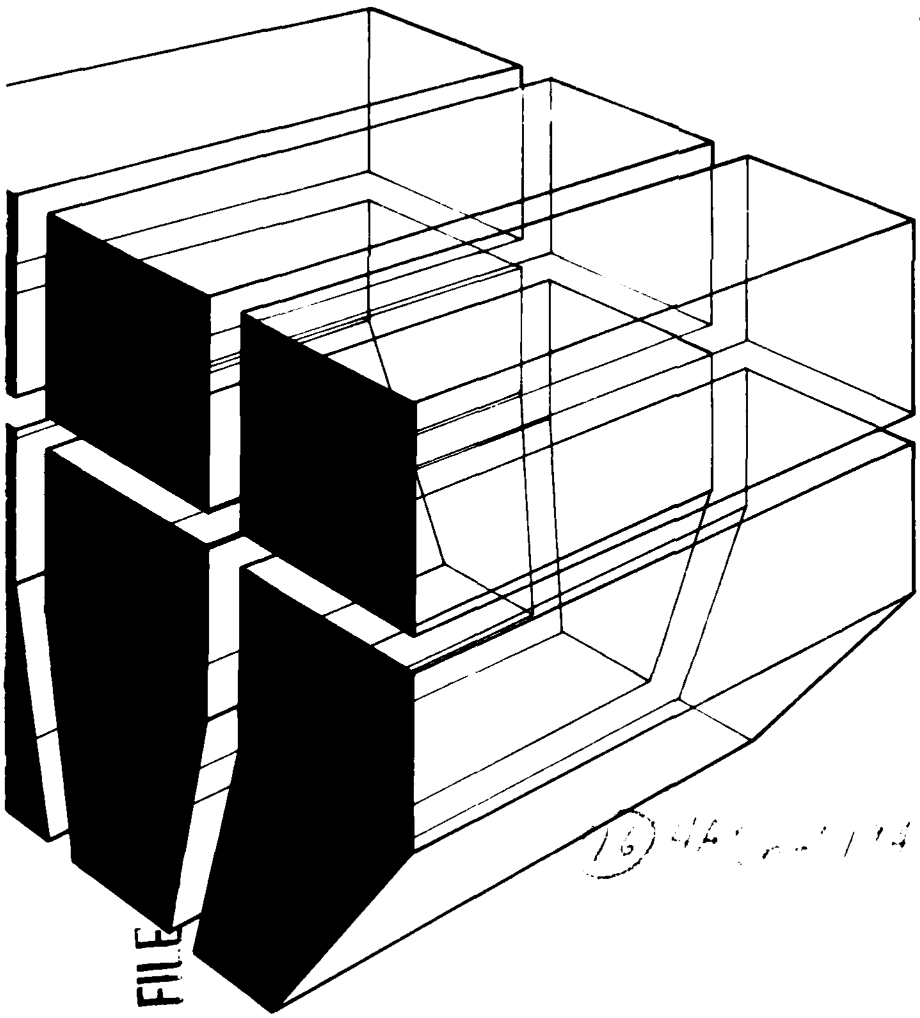

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Barry J. Dempsey

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A heat-transfer model was used to conduct a comprehensive study of nine composite roof systems for six building structures subjected to weather conditions at Cape Hatteras, NC. Based on analysis of the time-temperature regimes in the roof systems, numerous temperature and durability parameters were determined quantitatively. The durability parameters evaluated included the number of freeze-thaw cycles, rates of temperature change, lengths of freezing and thawing periods, and the range of temperature change. The thermal strains

Block 20 continued.

in the various roofing layers were determined for unbonded interface conditions, and the transient heat flux was determined for the nine roof systems.

FOREWORD

This project was performed for the Directorate of Military Programs, Office of the Chief of Engineers (OCE) under Project 4A76271AT41, "Military Facilities Engineering Technology"; Task B, "Facilities Operation and Maintenance"; Work Unit 022, "Improved Roofing Materials and Systems."

The work was performed by Dr. B. J. Dempsey, Consulting Engineer, Urbana, IL, for the Engineering and Materials Division (EM) of the U.S. Army Construction Engineering Research Laboratory (CERL), Champaign, IL. The project was done under Purchase Order DACA 88-79-M-0009, issued 20 October 1978, with Modification No. P00001, dated 2 November 1978.

Mr. John Ichter, DAEN-MPE-S, was the OCE Technical Monitor. Dr. Eugene Marvin and Mr. Myer Rosenfield were the CERL project coordinators.

Dr. R. Quattrone is Chief of CERL-EM. COL L. J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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A STUDY OF CLIMATIC EFFECTS ON ROOF SYSTEMS
AT CAPE HATTERAS, NORTH CAROLINA

1 INTRODUCTION

Problem Statement

Roofing systems currently used at military installations are generally short-lived for a variety of reasons. One major factor contributing to roof deterioration is the stress caused by the effects of climate (e.g., freeze-thaw cycles, exposure to temperature extremes, ultraviolet radiation, high winds, and hail).

Short-lived roofing has created unacceptably high life-cycle costs. For example, in FY78 the Government spent $54 million on reroofing at military installations, and $28 million during the first quarter of FY79. To help reduce these costs, the U.S. Army Construction Engineering Research Laboratory (CERL) is studying the effects of climate on several types of roofing systems in order to find which ones perform best under the various climatic stresses.

Background

The basic components of a composite roof system are the structural deck, vapor barrier, insulation, and built-up membrane. The structural deck and built-up membrane are common to all roof systems and are necessary for strength and weatherproofing. An insulating layer between the deck and membrane is being used more widely in modern roof construction to decrease heating and cooling costs. The vapor barrier is an impermeable membrane normally placed on the structural deck to prevent the flow of water vapor into the insulation or built-up membrane.

Brotherson[1] has discussed many causes of built-up roofing (BUR) failures. Griffin[2] has indicated that 10 to 15 percent of the built-up roofs in the United States fail prematurely. He has indicated that in severely cold regions, the incidence of roof problems exceeds the national average.

Climate greatly influences the performance of composite roof systems. Wrinkling, splitting, blistering, delamination, and alligatoring are a few of the climate-related distresses which can occur in the built-up membrane. Epstein and Putnam[3] have indicated that cyclic freezing and thawing can

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[1] D. E. Brotherson, "An Investigation into the Causes of Built-Up Roofing Failures," Research Report 61-2 (University of Illinois, October 1961), pp 1-10.

[2] C. W. Griffin, Manual of Built-Up Roof Systems (McGraw-Hill, 1970).

[3] K. A. Epstein and L. E. Putnam, "Performance Criteria for the Protected Membrane Roof Systems," Proceedings of the Symposium on Roofing Technology (National Bureau of Standards and National Roofing Contractors Association, September 1977), pp 49-60.

increase water absorption in insulating material and reduce thermal resistance. Lee, Dupuis, and Johnson[4] and Cash[5] have noted that thermally generated stresses can develop in built-up roof systems as a result of temperature changes. Cracking and deterioration of concrete as a result of freeze-thaw action is well documented. The accumulation of water often contributes to problems of durability in composite roof systems. Water vapor tends to diffuse through composite roof systems from a warm, humid interior to a cold, dry exterior. Laaly[6] has indicated that freeze-thaw cycles decreased the strength of immersed, asphalt-based, built-up membranes from 14 to 19 percent of dry strength for one cycle to 11 percent for 10 cycles.

Griffin[7] has indicated that there are appropriate American Society for Testing and Materials (ASTM) and Federal standards for testing important properties of component materials such as the surfacing aggregates, felts, bitumens, insulation, vapor barriers, and structural decks used in roofing systems. However, he states that there are no generally accepted tests for performance of composite roof systems assembled from these components. For performance evaluation of composite roof systems, researchers recommend either modifying existing tests or developing new tests.

It is apparent that the temperature regime must be quantitatively characterized if the service life and performance of composite roof systems are to be predicted for a given climate. This report describes development of quantitative temperature parameters obtained through a theoretical heat-transfer model and the application of these parameters to evaluating the durability of composite roof systems.

These parameters are used to theoretically analyze the effects of the climate at Cape Hatteras on heat loss through building roofs. Three of the roofs included in this study are being built at each of three Army installations in CONUS. Behavior of these roofs will be monitored for 2 years and the results compared to the theoretical predictions.

Objective

The objective of this study is to analyze the influence of climate on the durability and performance of nine different roof systems at Cape Hatteras, NC.

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[4] J. W. Lee, R. M. Dupuis, and J. E. Johnson, "Experimental Determination of Temperature Induced Loads in BUR Systems," Proceedings of the Symposium on Roofing Technology (National Bureau of Standards and National Roofing Contractors Association, September 1977), pp 38-48.

[5] C. G. Cash, "Thermal Warp-A Hypothesis for Built-Up Roofing Splitting Failures," Roofing Systems, Special Technical Publication 603 (American Society for Testing Materials [ASTM] 1976), pp 114-131.

[6] H. O. Laaly, "Effects of Moisture and Freeze-Thaw Cycles on the Strength of Bituminous Built-Up Roofing Membranes," Proceedings of the Symposium on Roofing Technology (National Bureau of Standards and National Roofing Contractors Association, September 1977), pp 244-251.

[7] C. W. Griffin, Manual of Built-Up Roof Systems (McGraw-Hill, 1970).

Approach

The specific tasks performed in this study were:

1. Determining the temperature variation in the roof sections as a function of time and position

2. Quantitatively determining the pertinent temperature parameters in the various layers of the roof sections

3. Evaluating the thermal strain in the roofing layers

4. Determining the transient heat flux through the roof sections

5. Comparing the relative durabilities and performance levels of the roof systems

6. Providing recommendations for laboratory and field testing to verify roof performance in different climatic zones.

Mode of Technology Transfer

Technology transfer will be accomplished by preparation of new or revised military construction guide specifications for the types of roofs selected.

2 TESTING PROGRAM

Based on previous work by Dempsey[8] a finite-difference, heat-transfer model was used to compute the temperature regime and transient heat flux as a function of time for nine roof systems. In the transient heat-transfer model, the energy balance for an increment of time is expressed as:

Heat added to a nodal volume + Heat given up by a nodal volume + Heat stored in a nodal volume

The roof systems at Cape Hatteras were analyzed for Buildings 5, 18, 2, 3, 4, and 34, and identified according to building number and section thickness as 5, 12, 2, 3A, 3B, 4A, 4B, 34A, and 34B. Figures 1 through 9 show the representative composite roof systems studied, including the physical and thermal properties of the various roofing layers. The surface boundary temperatures of the roof systems were determined from climatic data and included meteorological parameters such as short-wave radiation, long-wave radiation, convection, and air temperature. Ten years of climatic data (July 1, 1967 through June 30, 1977) from Cape Hatteras, NC, were used as input. The boundary temperatures at the bottom of the roof systems were related to the expected interior room temperatures shown in Figures 1 through 9.

The literature provides a more comprehensive discussion of the heat transfer model's capabilities and validation.[9]

In previous work on roof systems, Dempsey[10] has indicated that the temperature parameters pertinent to durability and performance are:

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[8] B. J. Dempsey, A Heat-Transfer Model for Evaluating Frost Action and Temperature Related Effects in Multilayered Pavement Systems, Ph.D. Thesis (University of Illinois, 1969); B. J. Dempsey, "Quantitative Freezing and Thawing Parameters for Composite Roof Decks," ASTM Proceedings, First International Conference on Durability of Building Materials and Components (ASTM, 1978).

[9] B. J. Dempsey, Ph.D. Thesis; B. J. Dempsey, "Quantitative Freezing and Thawing Parameters for Composite Roof Decks"; M. R. Thompson and B. J. Dempsey, "Quantitative Characterization of Cyclic Freezing and Thawing in Stabilized Pavement Materials," Highway Research Record 304 (Highway Research Board, 1970) pp 38-44; B. J. Dempsey and M. R. Thompson, "A Heat-Transfer Model for Evaluating Frost Action and Temperature Related Effects in Multilayered Pavement Systems," Highway Research Record 342 (Highway Research Board, 1970), pp 39-56; C. R. Marek and B. J. Dempsey, "A Model Utilizing Climatic Factors for Determining Stresses and Deflections in Flexible Pavement Systems," Proceedings (The Third International Conference on the Structural Design of Asphalt Pavements, London, England, September 1972), pp 101-114; B. J. Dempsey and M. R. Thompson, "Effects of Freeze-Thaw Parameters on the Durability of Stabilized Materials," Highway Research Record 379 (Highway Research Board, 1972), pp 10-18.

[10] B. J. Dempsey, "Quantitative Freezing and Thawing Parameters to Composite Roof Decks."

1. Cooling rate

2. Temperature below freezing

3. Length of freezing period

4. Warming rate

5. Temperature above freezing

6. Length of thawing period

7. Number of freezing and thawing periods

8. Temperature variability

Figure 10 shows an idealized freeze-thaw cycle for a roof system. The quantitative parameters for the idealized freeze-thaw cycle are dependent on the geographical location, month in the freezing period, year, and location in the composite roof system. The freeze-thaw history at a selected point in the roof system can be simulated by developing an idealized freeze-thaw cycle for each winter month for a chosen number of years of climatic data and determining the number of freeze-thaw cycles that occurred during each month. Dempsey[11] has shown that statistical analyses of such data provide satisfactory information for quantitative characterization of the freeze-thaw environment. Furthermore, the data are valuable input for laboratory testing procedures when it is desirable to simulate field conditions.[12]

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[11]B. J. Dempsey, "Quantitative Freezing and Thawing Parameters for Composite Roof Decks."

[12]B. J. Dempsey, "A Programmed Freeze-Thaw Durability Testing Unit for Evaluating Paving Materials," Journal of Materials, Vol 7, No. 2 (ASTM, June 1972), pp 143-147.

3 DATA

Tables 1 through 7 show temperature parameter data for various layers and depths of Building 5's roof system for 10 years of climatic input. The data include average temperature above freezing, average temperature below freezing, average cooling rate, average warming rate, average length of freezing period, average length of thawing period, and average number of freeze-thaw cycles. The data are statistically summarized over the 10-year study period for each month and for the year.

In a similar manner, Tables 8 through 56 provide the data for roof systems 1B, 2, 3A, 3B, 4A, 4B, 34A, and 34B.

Table 57 presents the transient heat flux for the nine roof systems. These data are also statistically summarized over the 10-year study period for each month and for the year.

4 ANALYSIS AND DISCUSSION

Temperature Effects

Tables 1, 8, 15, 22, 29, 36, 43, and 50 present temperature data in the roofing systems for conditions above freezing. Tables 2, 9, 16, 23, 30, 37, 44, and 51 provide temperature data for conditions below freezing.

Analysis of the data indicates that the freezing gradient generally does not penetrate below the surface layer of the roof systems in Cape Hatteras. The freezing gradient was found to penetrate the existing built-up layer on Building 18 as well as the gravel layers in roof systems 3A, 3B, 4A, and 4B. There was also some penetration of the freezing gradient into the built-up layer in roof systems 3A and 3B; however, the underlying insulation layers in all of the roof systems were highly effective in preventing deeper penetration of the freezing gradients.

The temperature above freezing generally varied with time of year and depth in the roof system. The data indicated that the temperature variability for a specified month for the 10 years of climatic input was not large. The temperatures in the deeper layers of the roof systems were fairly uniform, since they were controlled by the building's interior room temperature.

Temperature variations can influence the thermal strain experienced by roofing layers. Table 58 shows thermal strains in the nine roof systems for temperature variations of plus and minus three standard deviations from the mean temperature for 10 years of climatic data. The thermal strains in Table 58 are computed for a condition of no bonding or restraint between roof system layers.

Analysis of the data indicates that the thermal strains in the GAF mineral shield on Building 4 (roof systems 4A and 4B) and the Ethylene Propylene Diene Monomer (EPDM) membrane on Building 34 (roof systems 34A and 34B) are reasonably larger. The 25-mil diathon coating on Building 5 and the 40-mil Gacoflex membrane on Building 18 also experience relatively large thermal strains. The probability of thermal cracking in these materials will depend on their stress-strain properties at various temperatures. Thermal strains may become more evident in these materials as they age and become less ductile.

The built-up layer in roof systems 18, 3A, and 3B may also be susceptible to thermal cracking. The layer of surface gravel in roof systems 3A and 3B has little influence on the temperature variability in the built-up layer.

Table 58 indicates that insulation layers are highly beneficial in decreasing temperature variability and, therefore, the thermal strain in composite roof systems. The data validate the benefits of the protected membrane

roof (PMR) concept discussed by Larsson, Ondrus, and Petersson.[13] In the PMR concept, the roofing membrane layer is sandwiched between the deck below and the insulation above. For the membrane, the PMR concept offers drastic reduction in temperature ranges (thermal strain) and protection from chemicals, radiation, and physical hazards.

Cooling and Warming Rates

Tables 3, 10, 17, 24, 31, 38, 45, and 52 provide data for cooling rates in the composite roof systems. Tables 4, 11, 18, 25, 32, 39, 46, and 53 present the warming rate data.

Generally, the time of year did not greatly influence the cooling rate at specified depths in a given roof system. Except for Building 18, the surface cooling rate generally varied from about 2.0°F/hr (1.11°C/hr) to 2.5°F/hr (1.39°C/hr). The surface cooling rate for Building 18 varied from about 1.5°F/hr (0.83°C/hr) to 2.0°F/hr (1.11°C/hr).

The cooling rates were found to decrease with depth in the roof system and the type of layer material. Figures 11, 12, and 13 show the average annual cooling rates for the nine roof systems as a function of section depth.

Roof systems 5, 18, 2, 3A, 4A, 34A, and 34B experienced rather rapid decreases in the cooling rate as the section depth increased. It is interesting to note that the thicker roof systems (3B and 4B) showed a slower decrease in cooling rate with depth. Figure 12 indicates that increasing the thickness of the insulation layers in roof systems 3B and 4B did not substantially reduce the surface cooling rate from that shown for roof systems 3A and 4A.

The lower cooling rates noted for Building 18 (Figure 2) may be caused partly by the bright white surface of the Gacoflex and the higher interior room temperature of 85°F (29.4°C).

Except for the magnitude of the values, the warming rates shown in Tables 4, 11, 18, 25, 32, 39, 46, and 53 displayed the same trends as the cooling rates. Figures 14, 15, and 16 indicate that the annual warming rate was greatest at the surface of the roofing systems and decreased with depth in the sections. The surface warming rate varied from about 4.0°F/hr (2.22°C/hr) to 5.0°F/hr (2.78°C/hr) for all roof systems except on Building 18, which was about 3.5°F/hr (1.94°C/hr).

The significance of the effect of cooling and warming rates on roof systems may be how they influence the thermal strain rate. It is evident that with larger cooling and warming rates at the roof surface, materials at the surface would experience faster strain rates than materials deeper in the section, where cooling and warming rates are smaller.

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[13] L. E. Larsson, J. Ondrus, B. Petersson, "The Protected Membrane Roof (PMR) - A Study Combining Field and Laboratory Tests," Proceedings of the Symposium on Roofing Technology (National Bureau of Standards and National Roofing Contractors Association, September 1977), pp 86-92.

Insulating layers helped decrease the rate of temperature change for both cooling and warming conditions. It would seem that the membrane protection of insulating layers can be effective in decreasing roof system durability failures. An additional benefit derived from insulation layers is moderation of the differential thermal strains occurring in the roofing layers as a result of differences in temperature, cooling rate, and warming rate.

Length of Freezing and Thawing Periods

Tables 5, 12, 19, 26, 33, 40, 47, and 54 present the average length of the thawing period in the roof systems during freeze-thaw cycles. Similarly, Tables 6, 13, 20, 27, 34, 41, 48, and 55 show the average length of the freezing period. Freezing is assumed to occur at 31°F (-0.5°C) in this study. The data indicate that freezing and thawing are generally confined to the surface layers of the roof systems. The average durations of the freezing periods are very short and indicate the influence of diurnal winter temperatures on roof system durability. Most of the freezing and thawing occurs during the winter months of December, January, February, and March. The duration of the freezing period increases, and the duration of the thawing period decreases during the colder months of January and February, indicating the larger number of freeze-thaw cycles which occur at that time. Freezing periods of short duration are probably less detrimental to the roofing layers than those of long duration because less moisture transfer results from freezing gradients and therefore less ice accumulates in the layers.

Number of Freeze-Thaw Cycles

Tables 7, 14, 21, 28, 35, 42, 49, and 56 show the number of freeze-thaw cycles in the roof systems. Figure 17 summarizes the average annual number of freeze-thaw cycles at various depths in the roof systems on the different buildings. As noted in the tables and in Figure 17, most freeze-thaw cycles occurred at the surface (0.0 in. [0.0 cm]) of the roof systems. The built-up roofing layers on Buildings 18 and 3 (roof systems 3A and 3B) also experienced cyclic freeze-thaw action at depths of 0.5 in. (1.27 cm) and 1.0 in. (2.54 cm). Some freeze-thaw cycles are noted in the insulating layers of roof systems 4A and 4B. It is apparent that the gravel surface layers on roof systems 3A and 3B have little insulating value to freeze-thaw temperatures. In all of the roofing systems, 1 to 2 in. (2.54 to 5.08 cm) of insulation were adequate for preventing cyclic freeze-thaw action.

Epstein and Putnam[14] have indicated that insulation must be resistant to water and to freeze-thaw action. They found that water absorption by various insulations after freeze-thaw exposure could range from less than 10 percent to more than 80 percent during a 10-year period. They also indicated that 500 to 700 freeze-thaw cycles would be a conservative estimate for most locations during a typical 10-year period. Figure 17 shows that the upper roofing

[14] K. A. Epstein and L. E. Putnam, "Performance Criteria for the Protected Membrane Roof Systems," Proceedings of the Symposium on Roofing Technology (National Bureau of Standards and National Roofing Contractors Association, September, 1977), pp 49-60.

layers at Cape Hatteras would experience an average of 200 to 600 freeze-thaw cycles during a 10-year period. As shown in Tables 7, 14, 21, 28, 35, 42, 49, and 56, the number of freeze-thaw cycles over a 10-year period at $\overline{X} + 3\sigma$ would range from about 200 to 900.

Cyclic freezing and thawing could have detrimental effects on the durability of built-up roofing layers on Buildings 18 and 3, as well as on the three-ply GAF mineral shield layer on Building 4. It is important to use durable materials at the surface of roof systems so that splitting, blistering, delamination, alligatoring, and other durability failures can be minimized. The smaller number of freeze-thaw cycles noted at the roof surface on Building 18 is caused partly by the higher interior room temperature of 85°F (29.4°C) (see Figure 17).

Transient Heat Flux

Table 57 presents the transient heat flux for the roof systems studied. Figures 18 and 19 show the average heat flux for each month analyzed. As expected, heat was transferred into the roof system during the summer and out of the roof system during the winter.

Roof systems 5, 4B, 34A, and 34B displayed the lowest flux values in both winter and summer weather. Roof systems 18, 2, and 3A showed high values of heat flux. Roof systems 3B and 4A displayed intermediate flux values. The large flux loss noted for Building 18 (Figure 2) was probably influenced by the 85°F (29.4°C) interior temperature used in the analysis. However, the 80°F (26.7°C) interior temperature used in the analysis of Building 5 (Figure 1) did not cause a large flux loss. The greater insulation thickness and the 1 in. (2.54 cm) of gypsum concrete improved the thermal efficiency of Building 5 over that of Building 18. Although the roof system on Building 2 is very deep, Figure 18 shows that the heat flux is large in both summer and winter. This would indicate that the thermal efficiency of a roofing system is not always a function of total thickness, but that it is a function of layer combinations, type of insulation, layer thickness, and temperature differentials.

5 SUMMARY AND CONCLUSIONS

Summary

In previous work, Dempsey[15] has found that freeze-thaw cycles, cooling rate, freezing period, and freezing temperature were the most important parameters affecting the durability of roofing materials. These parameters are important, since it is the combination of a slow cooling or freezing rate and freeze-thaw cycles that often causes moisture buildup and associated durability problems in the various roofing layers. In addition, the rate of temperature change and the magnitude of temperature can be expected to influence the rate and magnitude of strain.

Table 59 ranks the roof systems in relation to the computed parameters. In terms of freeze-thaw cycles, the roof systems with surface layers of aggregate displayed fewer numbers of freeze-thaw cycles and therefore should provide better durability properties.

The lower the cooling rate is, the higher is the potential of moisture transfer; thus, more damage can occur.

When evaluated alone, the length of the freezing period is not a major influence on roof performance; however, it does contribute to the freeze-thaw durability.

The thermal strain in the upper layers of the roof systems is an important temperature parameter influencing roof performance. Roof systems having an insulation layer beneath an aggregate layer displayed the lowest thermal strains (Table 58).

The thermal efficiency of the roof structures is based on the heat flux during the year. The magnitude of the heat flux appears to be controlled by factors other than insulation layer thickness and roof system thickness. In transient heat-transfer analysis, it is evident that the heat storage capabilities of the layers are also important in determining the magnitude of the heat flux gained or lost through the roof system.

In summary, the performance of the roof systems analyzed in this study appear to depend on how well they resist the climate parameters which cause distress.

Conclusions

The following conclusions have been drawn from this study:

[15] B. J. Dempsey, "Quantitative Freezing and Thawing Parameters for Composite Roof Decks," ASTM Proceedings, First International Conference on Durability of Building Materials and Components (ASTM, 1978).

1. Materials of high quality and durability are required at the roof surface because of the temperature variability and freeze-thaw action which occur there.

2. Insulating materials help moderate the rate and magnitude of temperature changes in roof systems; however, insulation may increase the severity of climatic effects on surface membranes.

3. The data obtained in this study showed that membrane roofs in which the roofing membrane layer is sandwiched between the deck below and the insulation above are subjected to fewer freeze-thaw cycles and less thermal strain.

4. Transient heat flux in composite roof systems is related to layer thickness, layer thermal properties, and layer physical properties. Total roof thickness alone is not indicative of thermal efficiency.

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Table 1

Average Temperature Above Freezing for Roof System 5, °F

Building Identification		5			
Roofing Layer		25 mil Diathon	Polyuretnane Foam	Gypsum Concrete	Gypsum Plank
Depth in Section (in.)		0.0	1.0	3.0	4.0
July	$\bar{X}$	97.00	88.93	81.16	80.53
	σ	2.63	1.43	0.24	0.13
	V,%	2.71	1.61	0.30	0.16
August	$\bar{X}$	94.11	87.36	81.03	80.47
	σ	3.32	1.83	0.34	0.18
	V,%	3.53	2.09	0.42	0.23
September	$\bar{X}$	84.17	82.07	80.14	80.04
	σ	3.11	1.78	0.35	0.21
	V,%	3.69	2.17	0.44	0.26
October	$\bar{X}$	74.53	76.84	79.12	79.53
	σ	1.34	0.78	0.18	0.13
	V,%	1.80	1.02	0.22	0.16
November	$\bar{X}$	61.11	68.15	77.33	78.63
	σ	1.90	1.54	0.33	0.17
	V,%	3.00	2.27	0.43	0.21
December	$\bar{X}$	57.14	63.84	76.46	78.20
	σ	2.18	1.66	0.33	0.20
	V,%	3.82	2.60	0.44	0.25
January	$\bar{X}$	55.04	60.16	75.70	77.82
	σ	1.83	1.16	0.25	0.15
	V,%	3.33	1.93	0.33	0.20
February	$\bar{X}$	59.05	62.62	76.18	78.05
	σ	4.10	1.94	0.39	0.20
	V,%	6.95	3.10	0.51	0.26
March	$\bar{X}$	63.57	67.18	77.08	78.50
	σ	3.71	1.81	0.36	0.20
	V,%	5.83	2.70	0.46	0.26
April	$\bar{X}$	70.61	73.70	78.26	79.09
	σ	1.62	1.16	0.26	0.18
	V,%	2.30	1.57	0.33	0.22
May	$\bar{X}$	81.04	79.63	79.26	79.58
	σ	1.72	0.98	0.22	0.13
	V,%	2.12	1.23	0.28	0.16
June	$\bar{X}$	89.92	84.78	80.26	80.08
	σ	1.49	0.79	0.11	0.06
	V,%	1.66	0.93	0.14	0.08
Year	$\bar{X}$	75.35	74.68	78.51	79.22
	σ	0.87	0.39	0.09	0.10
	V,%	1.15	0.53	0.11	0.12

°C = (°F - 32)/1.8

Table 2

Average Temperature Below Freezing for Roof System 5, °F

Building Identification		5			
Roofing Layer		25 mil Diathon	Polyurethane Foam	Gypsum Concrete	Gypsum Plank
Depth in Section (in.)		0.0	1.0	3.0	4.0
July	$\overline{X}$ σ V,%	---	---	---	---
August	$\overline{X}$ σ V,%	---	---	---	---
September	$\overline{X}$ σ V,%	---	---	---	---
October	$\overline{X}$ σ V,%	---	---	---	---
November	$\overline{X}$ σ V,%	26.53 3.49 13.16	---	---	---
December	$\overline{X}$ σ V,%	28.00 1.16 4.15	---	---	---
January	$\overline{X}$ σ V,%	25.14 2.74 10.89	---	---	---
February	$\overline{X}$ σ V,%	25.55 2.22 8.69	---	---	---
March	$\overline{X}$ σ V,%	26.20 1.21 4.62	---	---	---
April	$\overline{X}$ σ V,%	27.99 0.00 0.00	---	---	---
May	$\overline{X}$ σ V,%	---	---	---	---
June	$\overline{X}$ σ V,%	---	---	---	---
Year	$\overline{X}$ σ V,%	25.98 1.06 4.09	---	---	---

°C = (°F - 32)/1.8

Table 3

Average Cooling Rate for Roof System 5, $^{o}F/hr$

Building Identification		5			
Roofing Layer		25 mil Diathon	Polyurethane Foam	Gypsum Concrete	Gypsum Plank
Depth in Section (in.)		0.0	1.0	3.0	4.0
July	$\bar{X}$	1.98	1.06	0.29	0.13
	σ	0.16	0.09	0.03	0.02
	V,%	8.27	8.48	9.64	13.11
August	$\bar{X}$	2.11	1.13	0.27	0.08
	σ	0.24	0.13	0.04	0.01
	V,%	11.23	11.42	13.59	13.99
September	$\bar{X}$	2.35	1.23	0.15	0.08
	σ	0.18	0.10	0.01	0.01
	V,%	7.76	7.78	9.24	7.33
October	$\bar{X}$	2.27	1.16	0.13	0.07
	σ	0.17	0.09	0.01	0.01
	V,%	7.48	7.49	6.43	7.90
November	$\bar{X}$	2.22	1.13	0.12	0.06
	σ	0.17	0.09	0.01	0.01
	V,%	7.72	7.68	8.35	8.05
December	$\bar{X}$	2.08	1.05	0.12	0.06
	σ	0.16	0.08	0.01	0.00
	V,%	7.61	7.71	8.31	7.97
January	$\bar{X}$	2.08	1.05	0.12	0.06
	σ	0.15	0.08	0.01	0.00
	V,%	7.24	7.27	5.07	7.33
February	$\bar{X}$	2.34	1.19	0.14	0.07
	σ	0.29	0.15	0.02	0.01
	V,%	12.40	12.39	11.70	12.60
March	$\bar{X}$	2.58	1.33	0.17	0.08
	σ	0.20	0.11	0.01	0.01
	V,%	7.94	7.93	8.77	7.68
April	$\bar{X}$	2.45	1.30	0.23	0.08
	σ	0.16	0.09	0.01	0.01
	V,%	6.51	6.58	4.94	7.69
May	$\bar{X}$	2.24	1.20	0.31	0.11
	σ	0.10	0.05	0.02	0.01
	V,%	4.28	4.39	5.06	8.23
June	$\bar{X}$	2.03	1.09	0.30	0.15
	σ	0.14	0.07	0.02	0.01
	V,%	6.81	6.86	7.18	7.22
Year	$\bar{X}$	2.23	1.16	0.18	0.08
	σ	0.06	0.03	0.01	0.00
	V,%	2.65	2.65	3.10	2.95

°C/hr = (°F/hr)/1.8

Table 4

Average Warming Rate for Roof System 5, °F

Building Identification		5			
Roofing Layer		25 mil Diathon	Polyurethane Foam	Gypsum Concrete	Gypsum Plank
Depth in Section (in.)		0.0	1.0	3.0	4.0
July	$\bar{X}$	4.86	2.82	0.27	0.13
	σ	0.44	0.26	0.03	0.01
	V,%	9.01	9.25	9.25	8.09
August	$\bar{X}$	5.24	2.92	0.25	0.16
	σ	0.65	0.37	0.03	0.02
	V,%	12.51	12.64	11.84	9.82
September	$\bar{X}$	5.12	2.34	0.33	0.17
	σ	0.44	0.19	0.02	0.01
	V,%	8.67	7.97	6.37	7.99
October	$\bar{X}$	2.66	1.52	0.29	0.15
	σ	0.20	0.11	0.03	0.01
	V,%	7.52	7.48	8.85	7.32
November	$\bar{X}$	2.62	1.49	0.27	0.14
	σ	0.21	0.12	0.02	0.01
	V,%	8.10	8.11	7.85	8.20
December	$\bar{X}$	2.42	1.38	0.23	0.13
	σ	0.16	0.09	0.02	0.01
	V,%	6.69	6.62	7.52	8.38
January	$\bar{X}$	2.38	1.36	0.23	0.13
	σ	0.18	0.10	0.02	0.01
	V,%	7.57	7.57	9.64	8.69
February	$\bar{X}$	2.81	1.60	0.29	0.16
	σ	0.41	0.23	0.04	0.02
	V,%	14.66	14.54	14.88	14.07
March	$\bar{X}$	4.26	2.04	0.34	0.18
	σ	0.41	0.18	0.03	0.02
	V,%	9.69	8.80	9.09	8.60
April	$\bar{X}$	6.03	3.17	0.29	0.20
	σ	0.35	0.19	0.02	0.01
	V,%	5.84	5.94	7.71	6.24
May	$\bar{X}$	5.54	3.18	0.29	0.16
	σ	0.27	0.16	0.01	0.00
	V,%	4.91	5.03	4.89	3.21
June	$\bar{X}$	5.01	2.91	0.29	0.13
	σ	0.38	0.22	0.02	0.01
	V,%	7.49	7.61	7.66	7.54
Year	$\bar{X}$	4.08	2.23	0.28	0.15
	σ	0.11	0.06	0.01	0.[illegible]
	V,%	2.79	2.67	2.50	2.55

°C/hr = (°F/hr)/1.8

Table 5

Average Length of Freezing Period for Roof System 5, Days

Building Identification		5			
Roofing Layer		25 mil Diathon	Polyurethane Foam	Gypsum Concrete	Gypsum Plank
Depth in Section (in.)		0.0	1.0	3.0	4.0
July	$\overline{X}$ σ V,%	---	---	---	---
August	$\overline{X}$ σ V,%	---	---	---	---
September	$\overline{X}$ σ V,%	---	---	---	---
October	$\overline{X}$ σ V,%	---	---	---	---
November	$\overline{X}$ σ V,%	0.10 0.09 90.97	---	---	---
December	$\overline{X}$ σ V,%	0.12 0.04 32.18	---	---	---
January	$\overline{X}$ σ V,%	0.21 0.08 38.49	---	---	---
February	$\overline{X}$ σ V,%	0.16 0.05 29.21	---	---	---
March	$\overline{X}$ σ V,%	0.12 0.03 22.64	---	---	---
April	$\overline{X}$ σ V,%	0.02 0.04 200.00	---	---	---
May	$\overline{X}$ σ V,%	---	---	---	---
June	$\overline{X}$ σ V,%	---	---	---	---
Year	$\overline{X}$ σ V,%	0.16 0.03 16.66			

Table 6

Average Length of Thawing Period for Roof System 5, Days

Building Identification		5			
Roofing Layer		25 mil Diathon	Polyurethane Foam	Gypsum Concrete	Gypsum Plank
Depth in Section (in.)		0.0	1.0	3.0	4.0
July	$\bar{X}$ σ V,%	---	---	---	---
August	$\bar{X}$ σ V,%	---	---	---	---
September	$\bar{X}$ σ V,%	---	---	---	---
October	$\bar{X}$ σ V,%	---	---	---	---
November	$\bar{X}$ σ V,%	12.30 11.82 96.11	---	---	---
December	$\bar{X}$ σ V,%	2.75 1.08 39.18	---	---	---
January	$\bar{X}$ σ V,%	1.36 0.26 18.89	---	---	---
February	$\bar{X}$ σ V,%	1.77 0.55 31.00	---	---	---
March	$\bar{X}$ σ V,%	3.57 1.80 50.41	---	---	---
April	$\bar{X}$ σ V,%	26.24 7.52 28.65	---	---	---
May	$\bar{X}$ σ V,%	---	---	---	---
June	$\bar{X}$ σ V,%	---	---	---	---
Year	$\bar{X}$ σ V,%	6.18 0.48 7.74			

Table 7

Average Number of Freeze-Thaw Cycles for Roof System 5

Building Identification		5			
Roofing Layer		25 mil Diathon	Polyurethane Foam	Gypsum Concrete	Gypsum Plank
Depth in Section (in.)		0.0	1.0	3.0	4.0
July	$\overline{X}$	---	---	---	---
	σ				
	V,%				
August	$\overline{X}$	---	---	---	---
	σ				
	V,%				
September	$\overline{X}$	---	---	---	---
	σ				
	V,%				
October	$\overline{X}$	---	---	---	---
	σ				
	V,%				
November	$\overline{X}$	2.75	0.00	0.00	0.00
	σ	1.89			
	V,%	68.84			
December	$\overline{X}$	10.75	0.00	0.00	0.00
	σ	3.30			
	V,%	30.74			
January	$\overline{X}$	19.25	0.00	0.00	0.00
	σ	2.87			
	V,%	14.92			
February	$\overline{X}$	14.75	0.00	0.00	0.00
	σ	5.56			
	V,%	37.70			
March	$\overline{X}$	9.00	0.00	0.00	0.00
	σ	4.55			
	V,%	50.51			
April	$\overline{X}$	0.25	0.00	0.00	0.00
	σ	0.50			
	V,%	200.00			
May	$\overline{X}$	---	---	---	---
	σ				
	V,%				
June	$\overline{X}$	---	---	---	---
	σ				
	V,%				
Year	$\overline{X}$	56.75	0.00	0.00	0.00
	σ	4.57			
	V,%	8.06			

Table 8

Average Temperature Above Freezing for Roof System 18, °F

Building Identification		18			
Roofing Layer		Gacoflex	Built-Up Roofing	Insulation	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	2.5
July	$\overline{X}$	87.59	86.90	86.01	85.01
	σ	1.30	1.15	0.74	0.20
	V,%	1.48	1.32	0.86	0.23
August	$\overline{X}$	86.20	85.68	85.30	84.93
	σ	1.76	1.60	1.04	0.25
	V,%	2.04	1.87	1.22	0.29
September	$\overline{X}$	79.34	79.67	81.49	84.13
	σ	2.33	2.17	1.42	0.34
	V,%	2.94	2.73	1.74	0.41
October	$\overline{X}$	71.49	72.51	76.84	83.06
	σ	1.97	1.83	1.19	0.31
	V,%	2.76	2.52	1.55	0.37
November	$\overline{X}$	59.67	60.86	69.07	81.24
	σ	1.94	1.82	1.40	0.34
	V,%	3.26	2.99	2.02	0.42
December	$\overline{X}$	55.57	56.62	66.02	80.53
	σ	3.07	3.50	2.38	0.56
	V,%	5.52	6.18	3.60	0.69
January	$\overline{X}$	52.55	52.76	62.46	79.71
	σ	2.79	3.48	2.78	0.65
	V,%	5.30	6.59	4.44	0.82
February	$\overline{X}$	54.12	54.77	63.24	79.88
	σ	2.32	2.36	1.67	0.39
	V,%	4.29	4.31	2.63	0.49
March	$\overline{X}$	58.95	59.89	67.84	80.95
	σ	2.01	1.75	1.79	0.43
	V,%	3.41	2.93	2.65	0.53
April	$\overline{X}$	66.07	67.02	72.98	82.09
	σ	1.75	1.63	1.31	0.33
	V,%	2.65	2.43	1.80	0.40
May	$\overline{X}$	74.62	74.79	78.13	83.19
	σ	1.51	1.38	0.88	0.21
	V,%	2.03	1.84	1.13	0.25
June	$\overline{X}$	83.17	82.72	83.25	84.33
	σ	1.73	1.60	1.04	0.24
	V,%	2.08	1.94	1.25	0.29
Year	$\overline{X}$	69.71	69.96	74.45	82.44
	σ	0.54	0.63	0.63	0.18
	V,%	0.77	0.90	0.84	0.21

°C = (°F - 32)/1.8

Table 9

Average Temperature Below Freezing for Roof System 18, °F

Building Identification		18			
Roofing Layer		Gacoflex	Built-Up Roofing	Insu-lation	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	2.5
July	$\bar{X}$				
	σ	---	---	---	---
	V,%				
August	$\bar{X}$				
	σ	---	---	---	---
	V,%				
September	$\bar{X}$				
	σ	---	---	---	---
	V,%				
October	$\bar{X}$				
	σ	---	---	---	---
	V,%				
November	$\bar{X}$	28.74	28.38		
	σ	2.61	0.00	---	---
	V,%	9.07	0.00		
December	$\bar{X}$	28.56	30.30		
	σ	1.55	1.41	---	---
	V,%	5.43	4.65		
January	$\bar{X}$	26.58	28.70		
	σ	3.36	2.64	---	---
	V,%	12.64	9.21		
February	$\bar{X}$	27.11	28.81		
	σ	1.49	1.00	---	---
	V,%	5.49	3.45		
March	$\bar{X}$	27.81	29.22		
	σ	0.78	1.79	---	---
	V,%	2.80	6.13		
April	$\bar{X}$	28.63	31.31		
	σ	0.44	0.43	---	---
	V,%	1.55	1.36		
May	$\bar{X}$				
	σ	---	---	---	---
	V,%				
June	$\bar{X}$				
	σ	---	---	---	---
	V,%				
Year	$\bar{X}$	27.38	28.87		
	σ	1.26	1.27		
	V,%	4.60	4.39		

°C = (°F - 32)/1.8

Table 10

Average Cooling Rate for Roof System 18, $^{o}F/hr$

Building Identification		18			
Roofing Layer		Gacoflex	Built-Up Roofing	Insu-lation	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	2.5
July	$\bar{X}$	1.62	1.62	1.08	0.27
	σ	0.14	0.15	0.10	0.03
	V,%	8.95	9.02	9.09	9.43
August	$\bar{X}$	1.74	1.73	1.14	0.27
	σ	0.14	0.14	0.10	0.02
	V,%	8.18	8.32	8.44	8.97
September	$\bar{X}$	1.84	1.77	1.15	0.26
	σ	0.12	0.12	0.08	0.02
	V,%	6.65	6.68	6.71	6.92
October	$\bar{X}$	1.60	1.53	1.00	0.23
	σ	0.18	0.17	0.11	0.03
	V,%	11.03	11.03	11.06	11.23
November	$\bar{X}$	1.62	1.55	1.01	0.23
	σ	0.13	0.12	0.08	0.02
	V,%	7.84	7.88	7.87	7.83
December	$\bar{X}$	1.44	1.38	0.90	0.20
	σ	0.16	0.15	0.10	0.02
	V,%	11.23	11.20	11.20	11.18
January	$\bar{X}$	1.45	1.40	0.91	0.20
	σ	0.11	0.11	0.07	0.02
	V,%	7.63	7.65	7.71	8.05
February	$\bar{X}$	1.71	1.64	1.07	0.24
	σ	0.20	0.19	0.12	0.03
	V,%	11.49	11.50	11.49	11.42
March	$\bar{X}$	1.95	1.87	1.21	0.27
	σ	0.19	0.18	0.12	0.03
	V,%	9.51	9.51	9.52	9.63
April	$\bar{X}$	2.01	1.97	1.29	0.30
	σ	0.15	0.14	0.09	0.02
	V,%	7.33	7.24	7.19	6.95
May	$\bar{X}$	1.84	1.83	1.21	0.29
	σ	0.16	0.16	0.11	0.03
	V,%	8.49	8.59	8.66	9.00
June	$\bar{X}$	1.71	1.71	1.14	0.28
	σ	0.10	0.10	0.07	0.02
	V,%	5.88	5.89	5.89	5.87
Year	$\bar{X}$	1.71	1.67	1.09	0.25
	σ	0.08	0.08	0.05	0.01
	V,%	4.84	4.82	4.83	4.92

°C/hr = (°F/hr)/1.8

Table 11

Average Warming Rate for Roof System 18, $^{o}F/hr$

Building Identification		18			
Roofing Layer		Gacoflex	Built-Up Roofing	Insu-lation	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	2.5
July	$\bar{X}$	3.24	3.24	2.16	0.53
	σ	0.27	0.27	0.18	0.05
	V,%	8.35	8.44	8.51	8.86
August	$\bar{X}$	3.47	3.44	2.27	0.54
	σ	0.27	0.28	0.18	0.05
	V,%	7.86	8.02	8.14	8.69
September	$\bar{X}$	3.63	3.50	2.28	0.52
	σ	0.25	0.24	0.16	0.04
	V,%	6.77	6.78	6.82	7.00
October	$\bar{X}$	3.17	3.04	1.98	0.45
	σ	0.32	0.31	0.20	0.05
	V,%	10.23	10.24	10.27	10.43
November	$\bar{X}$	3.18	3.05	1.99	0.44
	σ	0.27	0.26	0.17	0.04
	V,%	8.52	8.54	8.53	8.48
December	$\bar{X}$	2.88	2.77	1.80	0.40
	σ	0.30	0.28	0.19	0.04
	V,%	10.29	10.29	10.29	10.42
January	$\bar{X}$	2.89	2.78	1.81	0.40
	σ	0.24	0.23	0.15	0.04
	V,%	8.35	8.33	8.38	8.70
February	$\bar{X}$	3.45	3.30	2.15	0.48
	σ	0.42	0.40	0.26	0.06
	V,%	12.20	12.20	12.18	12.12
March	$\bar{X}$	3.91	3.74	2.44	0.55
	σ	0.38	0.36	0.24	0.05
	V,%	9.71	9.72	9.74	9.90
April	$\bar{X}$	4.07	3.99	2.62	0.60
	σ	0.25	0.24	0.16	0.03
	V,%	6.05	6.02	5.97	5.76
May	$\bar{X}$	3.71	3.69	2.45	0.59
	σ	0.35	0.35	0.23	0.06
	V,%	9.35	9.40	9.45	9.71
June	$\bar{X}$	3.46	3.45	2.31	0.57
	σ	0.22	0.22	0.14	0.04
	V,%	6.34	6.31	6.28	6.20
Year	$\bar{X}$	3.42	3.33	2.19	0.51
	σ	0.17	0.16	0.11	0.02
	V,%	4.86	4.83	4.83	4.84

°C/hr = (°F/hr)/1.8

Table 12

Average Length of Freezing Period for Roof System 18, Days

Building Identification		18			
Roofing Layer		Gacoflex	Built-Up Roofing	Insulation	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	2.5
July	$\bar{X}$				
	σ	---	---	---	---
	V,%				
August	$\bar{X}$				
	σ	---	---	---	---
	V,%				
September	$\bar{X}$				
	σ	---	---	---	---
	V,%				
October	$\bar{X}$				
	σ	---	---	---	---
	V,%				
November	$\bar{X}$	0.07			
	σ	0.08	---	---	---
	V,%	109.79			
December	$\bar{X}$	0.12			
	σ	0.06	---	---	---
	V,%	46.97			
January	$\bar{X}$	0.21			
	σ	0.13	---	---	---
	V,%	60.31			
February	$\bar{X}$	0.16			
	σ	0.05	---	---	---
	V,%	29.16			
March	$\bar{X}$	0.09			
	σ	0.05	---	---	---
	V,%	56.07			
April	$\bar{X}$	0.03			
	σ	0.04			
	V,%	149.69			
May	$\bar{X}$				
	σ	---	---	---	---
	V,%				
June	$\bar{X}$				
	σ	---	---	---	---
	V,%				
Year	$\bar{X}$	0.16			
	σ	0.04	---	---	---
	V,%	26.34			

Table 13

Average Length of Thawing Period for Roof System 18, °F

Building Identification		18			
Roofing Layer		Gacoflex	Built-Up Roofing	Insu-lation	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	2.5
July	$\overline{X}$ σ V,%	---	---	---	---
August	$\overline{X}$ σ V,%	---	---	---	---
September	$\overline{X}$ σ V,%	---	---	---	---
October	$\overline{X}$ σ V,%	---	---	---	---
November	$\overline{X}$ σ V,%	15.53 11.31 72.83	---	---	---
December	$\overline{X}$ σ V,%	7.65 4.68 61.18	---	---	---
January	$\overline{X}$ σ V,%	2.94 2.28 77.49	---	---	---
February	$\overline{X}$ σ V,%	2.83 1.26 44.36	---	---	---
March	$\overline{X}$ σ V,%	9.61 10.60 110.30	---	---	---
April	$\overline{X}$ σ V,%	24.15 9.20 38.09	---	---	---
May	$\overline{X}$ σ V,%	---	---	---	---
June	$\overline{X}$ σ V,%	---	---	---	---
Year	$\overline{X}$ σ V,%	11.78 5.13 43.53			

Table 14

Average Number of Freeze-Thaw Cycles for Roof System 18

Building Identification		18			
Roofing Layer		Gacoflex	Built-Up Roofing	Insu-lation	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	2.5
July	$\bar{X}$ σ V,%	---	---	---	---
August	$\bar{X}$ σ V,%	---	---	---	---
September	$\bar{X}$ σ V,%	---	---	---	---
October	$\bar{X}$ σ V,%	---	---	---	---
November	$\bar{X}$ σ V,%	1.83 1.60 87.39	0.50 1.22 244.95	0.00	0.00
December	$\bar{X}$ σ V,%	4.50 3.39 75.36	1.67 1.37 81.98	0.00	0.00
January	$\bar{X}$ σ V,%	11.83 5.04 42.56	5.83 4.45 76.22	0.00	0.00
February	$\bar{X}$ σ V,%	10.17 5.46 53.66	6.67 4.27 64.11	0.00	0.00
March	$\bar{X}$ σ V,%	4.50 3.27 72.69	2.50 2.81 112.43	0.00	0.00
April	$\bar{X}$ σ V,%	0.50 0.84 167.33	0.50 0.84 167.33	0.00	0.00
May	$\bar{X}$ σ V,%	---	---	---	---
June	$\bar{X}$ σ V,%	---	---	---	---
Year	$\bar{X}$ σ V,%	33.33 11.08 33.23	17.67 6.25 35.38	0.00	0.00

Table 15

Average Temperature Above Freezing for Roof System 2, ^{o}F

Building Identification		2				
Roofing Layer		No. 5 Gravel	Styrofoam Insulation	Built-Up Roofing	Gypsum Concrete	Gypsum Plank
Depth in Section (in.)		0.0	2.0	3.0	4.5	6.5
July	$\overline{X}$	92.56	83.96	76.11	74.54	72.87
	σ	1.78	1.03	0.36	0.24	0.09
	V,%	1.93	1.22	0.48	0.32	0.12
August	$\overline{X}$	90.85	83.08	75.82	74.40	72.82
	σ	2.21	1.34	0.54	0.35	0.17
	V,%	2.43	1.62	0.71	0.48	0.23
September	$\overline{X}$	83.39	78.64	74.00	73.09	72.32
	σ	2.49	1.58	0.69	0.48	0.19
	V,%	2.99	2.01	0.93	0.65	0.26
October	$\overline{X}$	74.54	73.10	71.58	71.42	71.70
	σ	1.84	1.20	0.59	0.43	0.18
	V,%	2.47	1.65	0.82	0.60	0.25
November	$\overline{X}$	61.77	64.21	67.57	68.63	70.65
	σ	1.86	1.46	0.69	0.49	0.20
	V,%	3.01	2.28	1.02	0.72	0.29
December	$\overline{X}$	58.11	60.65	66.01	67.55	70.25
	σ	2.68	2.44	1.16	0.83	0.32
	V,%	4.60	4.02	1.76	1.23	0.46
January	$\overline{X}$	56.22	56.99	64.34	66.38	69.81
	σ	1.76	2.76	1.35	0.97	0.39
	V,%	3.13	4.84	2.09	1.46	0.55
February	$\overline{X}$	58.82	58.34	64.79	66.65	69.90
	σ	3.27	1.71	0.77	0.55	0.23
	V,%	5.57	2.93	1.19	0.82	0.33
March	$\overline{X}$	63.95	63.79	67.19	68.30	70.51
	σ	2.54	1.81	0.84	0.60	0.24
	V,%	3.97	2.83	1.24	0.88	0.33
April	$\overline{X}$	70.51	69.63	69.75	70.08	71.18
	σ	1.55	1.42	0.66	0.47	0.19
	V,%	2.20	2.04	0.95	0.67	0.27
May	$\overline{X}$	79.10	75.30	72.17	71.78	71.83
	σ	2.03	1.20	0.46	0.30	0.14
	V,%	2.57	1.60	0.64	0.42	0.19
June	$\overline{X}$	88.02	80.93	74.62	73.48	72.47
	σ	1.91	1.19	0.52	0.36	0.17
	V,%	2.17	1.47	0.69	0.50	0.24
Year	$\overline{X}$	74.09	70.79	70.37	70.55	71.37
	σ	0.68	0.56	0.31	0.23	0.14
	V,%	0.92	0.79	0.44	0.32	0.20

°C = (°F - 32)/1.8

Table 16

Average Temperature Below Freezing for Roof System 2, ^{o}F

Building Identification		2				
Roofing Layer		No. 5 Gravel	Styrofoam Insulation	Built-Up Roofing	Gypsum Concrete	Gypsum Plank
Depth in Section (in.)		0.0	2.0	3.0	4.5	6.5
July	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
August	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
September	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
October	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
November	$\overline{X}$	26.28				
	σ	3.28	---	---	---	---
	V,%	12.47				
December	$\overline{X}$	27.94				
	σ	1.98	---	---	---	---
	V,%	7.09				
January	$\overline{X}$	24.80				
	σ	3.91	---	---	---	---
	V,%	15.77				
February	$\overline{X}$	25.45				
	σ	2.24	---	---	---	---
	V,%	8.81				
March	$\overline{X}$	27.30				
	σ	2.19	---	---	---	---
	V,%	8.02				
April	$\overline{X}$	28.82				
	σ	2.08	---	---	---	---
	V,%	7.21				
May	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
June	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
Year	$\overline{X}$	26.00				
	σ	1.29				
	V,%	4.95				

°C = (°F - 32)/1.8

Table 17

Average Cooling Rate for Roof System 2, $^{o}F/hr$

Building Identification		2				
Roofing Layer		No. 5 Gravel	Styrofoam Insulation	Built-Up Roofing	Gypsum Concrete	Gypsum Plank
Depth in Section (in.)		0.0	2.0	3.0	4.5	6.5
July	$\overline{X}$	2.47	1.51	0.46	0.24	0.07
	σ	0.23	0.14	0.05	0.03	0.01
	V,%	9.19	9.39	10.18	10.80	11.55
August	$\overline{X}$	2.63	1.59	0.47	0.24	0.07
	σ	0.24	0.15	0.05	0.03	0.01
	V,%	9.19	9.49	10.56	11.39	12.35
September	$\overline{X}$	2.65	1.56	0.44	0.22	0.06
	σ	0.19	0.11	0.03	0.02	0.01
	V,%	7.04	7.18	7.87	8.48	9.26
October	$\overline{X}$	2.28	1.33	0.36	0.18	0.05
	σ	0.26	0.15	0.04	0.02	0.01
	V,%	11.24	11.37	11.96	12.30	12.98
November	$\overline{X}$	2.19	1.27	0.33	0.16	0.04
	σ	0.17	0.10	0.03	0.01	0.00
	V,%	7.57	7.63	7.71	6.41	9.27
December	$\overline{X}$	1.90	1.09	0.28	0.13	0.03
	σ	0.21	0.12	0.03	0.01	0.00
	V,%	10.85	10.81	10.82	11.09	11.53
January	$\overline{X}$	1.93	1.11	0.28	0.13	0.03
	σ	0.16	0.09	0.02	0.01	0.00
	V,%	8.36	8.25	7.99	7.12	6.14
February	$\overline{X}$	2.34	1.35	0.35	0.17	0.04
	σ	0.26	0.15	0.04	0.01	0.00
	V,%	11.18	11.03	10.05	8.96	8.55
March	$\overline{X}$	2.73	1.58	0.43	0.21	0.06
	σ	0.26	0.15	0.04	0.02	0.00
	V,%	9.34	9.29	9.29	9.33	8.59
April	$\overline{X}$	2.91	1.73	0.49	0.25	0.07
	σ	0.19	0.11	0.03	0.01	0.00
	V,%	6.47	6.34	6.09	6.00	4.84
May	$\overline{X}$	2.76	1.67	0.50	0.26	0.07
	σ	0.24	0.15	0.05	0.03	0.01
	V,%	8.78	8.98	9.66	10.21	10.89
June	$\overline{X}$	2.61	1.60	0.49	0.26	0.07
	σ	0.15	0.09	0.03	0.02	0.00
	V,%	5.56	5.60	5.77	5.99	6.35
Year	$\overline{X}$	2.45	1.45	0.41	0.20	0.06
	σ	0.12	0.07	0.02	0.01	0.00
	V,%	4.87	4.87	5.09	5.01	4.68

°C/hr = (°F/hr)/1.8

Table 18

Average Warming Rate for Roof System 2, °F/hr

Building Identification		2				
Roofing Layer		No. 5 Gravel	Styrofoam Insulation	Built-Up Roofing	Gypsum Concrete	Gypsum Plank
Depth in Section (in.)		0.0	2.0	3.0	4.5	6.5
July	$\bar{X}$	4.95	3.03	0.93	0.50	0.14
	σ	0.43	0.27	0.09	0.05	0.01
	V,%	8.67	8.86	9.51	10.01	10.57
August	$\bar{X}$	5.24	3.16	0.93	0.48	0.13
	σ	0.47	0.29	0.10	0.05	0.02
	V,%	8.96	9.26	10.31	10.11	12.03
September	$\bar{X}$	5.25	3.08	0.86	0.43	0.12
	σ	0.38	0.23	0.07	0.04	0.01
	V,%	7.20	7.32	7.93	8.50	9.27
October	$\bar{X}$	4.52	2.63	0.72	0.35	0.09
	σ	0.47	0.28	0.08	0.04	0.01
	V,%	10.48	10.59	11.04	11.82	12.16
November	$\bar{X}$	4.31	2.49	0.64	0.30	0.07
	σ	0.35	0.20	0.05	0.03	0.01
	V,%	8.04	8.11	8.37	10.57	11.13
December	$\bar{X}$	3.80	2.19	0.55	0.24	0.05
	σ	0.38	0.22	0.05	0.03	0.01
	V,%	10.08	9.96	9.75	10.55	14.33
January	$\bar{X}$	3.86	2.21	0.55	0.24	0.05
	σ	0.34	0.19	0.05	0.02	0.01
	V,%	8.75	8.66	8.65	9.35	11.17
February	$\bar{X}$	4.72	2.72	0.71	0.33	0.08
	σ	0.55	0.32	0.08	0.04	0.01
	V,%	11.72	1.62	11.01	11.41	9.23
March	$\bar{X}$	5.47	3.17	0.86	0.42	0.11
	σ	0.53	0.31	0.09	0.04	0.01
	V,%	9.72	9.70	9.91	10.18	11.01
April	$\bar{X}$	5.89	3.50	0.99	0.50	0.14
	σ	0.30	0.17	0.05	0.02	0.01
	V,%	5.08	4.97	4.66	4.54	5.37
May	$\bar{X}$	5.55	3.37	1.00	0.52	0.15
	σ	0.53	0.33	0.10	0.06	0.02
	V,%	9.62	9.78	10.40	10.91	11.54
June	$\bar{X}$	5.27	3.23	1.00	0.53	0.15
	σ	0.31	0.19	0.06	0.03	0.01
	V,%	5.83	5.84	5.95	6.10	6.33
Year	$\bar{X}$	4.90	2.90	0.81	0.40	0.11
	σ	0.24	0.14	0.04	0.02	0.01
	V,%	4.88	4.87	4.97	5.41	6.16

°C/hr = (°F/hr)/1.8

Table 19

Average Length of Freezing Period for Roof System 2, Days

Building Identification		2				
Roofing Layer		No. 5 Gravel	Styrofoam Insulation	Built-Up Roofing	Gypsum Concrete	Gypsum Plank
Depth in Section (in.)		0.0	2.0	3.0	4.5	6.5
July	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
August	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
September	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
October	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
November	$\overline{X}$	0.09				
	σ	0.08	---	---	---	---
	V,%	91.20				
December	$\overline{X}$	0.11				
	σ	0.07	---	---	---	---
	V,%	60.98				
January	$\overline{X}$	0.21				
	σ	0.11	---	---	---	---
	V,%	54.54				
February	$\overline{X}$	0.15				
	σ	0.05	---	---	---	---
	V,%	33.20				
March	$\overline{X}$	0.09				
	σ	0.04	---	---	---	---
	V,%	47.36				
April	$\overline{X}$	0.03				
	σ	0.04	---	---	---	---
	V,%	135.67				
May	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
June	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
Year	$\overline{X}$	0.15				
	σ	0.03	--	---	---	---
	V,%	20.40				

Table 20

Average Length of Thawing Period for Roof System 2, Days

Building Identification		2				
Roofing Layer		No. 5 Gravel	Styrofoam Insulation	Built-Up Roofing	Gypsum Concrete	Gypsum Plank
Depth in Section (in.)		0.0	2.0	3.0	4.5	6.5
July	$\bar{X}$	---	---	---	---	---
	σ					
	V,%					
August	$\bar{X}$	---	---	---	---	---
	σ					
	V,%					
September	$\bar{X}$	---	---	---	---	---
	σ					
	V,%					
October	$\bar{X}$	---	---	---	---	---
	σ					
	V,%					
November	$\bar{X}$	15.52	---	---	---	---
	σ	11.32				
	V,%	90.44				
December	$\bar{X}$	6.36	---	---	---	---
	σ	4.94				
	V,%	77.69				
January	$\bar{X}$	2.66	---	---	---	---
	σ	2.38				
	V,%	89.54				
February	$\bar{X}$	2.34	---	---	---	---
	σ	0.84				
	V,%	36.13				
March	$\bar{X}$	6.16	---	---	---	---
	σ	4.83				
	V,%	78.48				
April	$\bar{X}$	20.40	---	---	---	---
	σ	10.80				
	V,%	52.94				
May	$\bar{X}$	---	---	---	---	---
	σ					
	V,%					
June	$\bar{X}$	---	---	---	---	---
	σ					
	V,%					
Year	$\bar{X}$	9.86				
	σ	4.87				
	V,%	49.44				

°C = (°F - 32)/1.8

Table 21

Average Number of Freeze-Thaw Cycles for Roof System 2

Building Identification		2				
Roofing Layer		No. 5 Gravel	Styrofoam Insulation	Built-Up Roofing	Gypsum Concrete	Gypsum Plank
Depth in Section (in.)		0.0	2.0	3.0	4.5	6.5
July	$\overline{X}$ σ V,%	---	---	---	---	---
August	$\overline{X}$ σ V,%	---	---	---	---	---
September	$\overline{X}$ σ V,%	---	---	---	---	---
October	$\overline{X}$ σ V,%	---	---	---	---	---
November	$\overline{X}$	1.83	0.00	0.00	0.00	0.00
	σ	1.60				
	V,%	87.39				
December	$\overline{X}$	6.33	0.00	0.00	0.00	0.00
	σ	4.72				
	V,%	74.51				
January	$\overline{X}$	14.00	0.00	0.00	0.00	0.00
	σ	6.20				
	V,%	44.26				
February	$\overline{X}$	11.67	0.00	0.00	0.00	0.00
	σ	5.39				
	V,%	46.21				
Marcy	$\overline{X}$	6.17	0.00	0.00	0.00	0.00
	σ	4.17				
	V,%	67.58				
April	$\overline{X}$	1.00	0.00	0.00	0.00	0.00
	σ	1.26				
	V,%	126.49				
May	$\overline{X}$ σ V,%	---	---	---	---	---
June	$\overline{X}$ σ V,%	---	---	---	---	---
Year	$\overline{X}$	41.00	0.00	0.00	0.00	0.00
	σ	14.37				
	V,%	35.04				

Table 22

Average Temperature Above Freezing for Roof System 3A, ^{o}F

Building Identification		3				
Roofing Layer		Light Colored Gravel		Built-up Roofing	Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	1.5	3.0
July	$\overline{X}$	92.65	92.39	90.64	83.22	73.90
	σ	2.00	1.98	1.80	1.08	0.21
	V,%	2.16	2.14	1.98	1.30	0.28
August	$\overline{X}$	90.71	90.50	89.07	82.36	73.82
	σ	2.44	2.41	2.24	1.37	0.27
	V,%	2.69	2.67	2.52	1.67	0.37
September	$\overline{X}$	83.31	80.25	82.66	78.51	73.14
	σ	2.76	2.75	2.60	1.60	0.3[illegible]
	V,%	3.31	3.30	3.15	2.04	0.4[illegible]
October	$\overline{X}$	74.96	74.99	74.95	73.77	72.25
	σ	1.63	1.62	1.52	0.95	0.20
	V,%	2.17	2.16	2.03	1.28	0.27
November	$\overline{X}$	61.74	61.63	62.31	65.33	70.64
	σ	1.56	1.85	1.74	1.38	0.28
	V,%	2.53	3.00	2.80	2.11	0.40
December	$\overline{X}$	58.14	57.93	57.68	61.91	69.99
	σ	2.77	2.75	2.92	2.22	0.43
	V,%	4.77	4.75	5.06	3.59	0.61
January	$\overline{X}$	56.55	56.24	56.19	58.76	69.40
	σ	1.71	1.86	2.18	2.67	0.51
	V,%	3.02	3.31	3.88	4.54	0.74
February	$\overline{X}$	59.38	59.19	58.61	60.37	69.70
	σ	3.98	3.61	3.28	1.72	0.33
	V,%	6.70	6.10	5.59	2.84	0.47
March	$\overline{X}$	64.33	64.16	63.57	64.87	70.55
	σ	2.80	2.80	1.96	1.56	0.31
	V,%	4.35	4.37	3.09	2.40	0.44
April	$\overline{X}$	70.33	70.24	69.96	70.18	71.52
	σ	1.44	1.43	1.48	1.21	0.25
	V,%	2.05	2.04	2.11	1.73	0.35
May	$\overline{X}$	79.01	78.80	77.81	75.32	72.42
	σ	2.12	2.09	1.91	1.16	0.22
	V,%	2.68	2.65	2.46	1.54	0.30
June	$\overline{X}$	87.87	87.60	86.02	80.33	73.31
	σ	1.92	1.91	1.77	1.09	0.22
	V,%	2.19	2.18	2.06	1.35	0.30
Year	$\overline{X}$	74.24	74.03	73.19	71.31	71.73
	σ	0.77	0.68	0.47	0.43	0.12
	V,%	1.04	0.92	0.64	0.60	0.16

°C = (°F - 32)/1.8

Table 23

Average Temperature Below Freezing for Roof System 3A, °F

Building Identification		3				
Roofing Layer		Light Colored Gravel		Built-Up Roofing	Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	1.5	3.0
July	$\bar{X}$ σ V,%	---	---	---	---	---
August	$\bar{X}$ σ V,%	---	---	---	---	---
September	$\bar{X}$ σ V,%	---	---	---	---	---
October	$\bar{X}$ σ V,%	---	---	---	---	---
November	$\bar{X}$ σ V,%	26.31 3.95 15.01	25.65 3.14 12.24	27.87 3.09 11.08	---	---
December	$\bar{X}$ σ V,%	27.79 1.49 5.35	27.77 1.58 5.68	28.51 1.43 5.03	---	---
January	$\bar{X}$ σ V,%	24.27 3.29 13.55	24.17 3.32 13.73	25.77 3.32 12.90	---	---
February	$\bar{X}$ σ V,%	25.99 1.94 7.46	25.99 2.05 7.88	26.66 1.72 6.46	---	---
March	$\bar{X}$ σ V,%	26.59 1.14 4.30	26.54 1.05 3.94	27.29 0.74 2.72	---	---
April	$\bar{X}$ σ V,%	28.41 1.80 6.33	28.20 1.75 6.19	29.15 2.28 7.81	---	---
May	$\bar{X}$ σ V,%	---	---	---	---	---
June	$\bar{X}$ σ V,%	---	---	---	---	---
Year	$\bar{X}$ σ V,%	26.07 1.18 4.54	25.92 1.27 4.89	26.82 1.42 5.29		

°C = (°F - 32)/1.8

Table 24

Average Cooling Rate for Roof System 3A, $^{o}F/hr$

Building Identification		3				
Roofing Layer		Light Colored Gravel		Built-Up Roofing	Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	1.5	3.0
July	$\overline{X}$	2.42	2.45	2.43	1.53	0.29
	σ	0.25	0.25	0.25	0.16	0.03
	V,%	10.20	10.22	10.33	10.42	10.90
August	$\overline{X}$	2.56	2.58	2.54	1.57	0.29
	σ	0.26	0.26	0.26	0.16	0.03
	V,%	10.01	10.05	10.19	10.31	10.95
September	$\overline{X}$	2.66	2.66	2.57	1.57	0.28
	σ	0.18	0.18	0.18	0.11	0.02
	V,%	6.89	6.90	6.91	6.96	7.32
October	$\overline{X}$	2.27	2.27	2.18	1.34	0.24
	σ	0.28	0.28	0.27	0.17	0.03
	V,%	12.33	12.34	12.38	12.43	12.72
November	$\overline{X}$	2.21	2.21	2.13	1.30	0.22
	σ	0.15	0.15	0.15	0.09	0.02
	V,%	6.76	6.78	6.87	6.92	7.17
December	$\overline{X}$	1.93	1.93	1.86	1.13	0.19
	σ	0.20	0.20	0.19	0.12	0.02
	V,%	10.25	10.24	10.22	10.21	10.21
January	$\overline{X}$	1.96	1.96	1.88	1.15	0.20
	σ	0.17	0.17	0.17	0.10	0.02
	V,%	8.94	8.92	8.90	8.93	9.19
February	$\overline{X}$	2.33	2.33	2.24	1.37	0.24
	σ	0.29	0.29	0.28	0.17	0.03
	V,%	12.42	12.42	12.44	12.43	12.27
March	$\overline{X}$	2.79	2.79	2.67	1.64	0.29
	σ	0.21	0.21	0.20	0.12	0.02
	V,%	7.56	7.55	7.51	7.53	7.69
April	$\overline{X}$	2.88	2.90	2.83	1.74	0.31
	σ	0.21	0.21	0.20	0.12	0.02
	V,%	7.26	7.24	7.18	7.15	7.00
May	$\overline{X}$	2.68	2.71	2.68	1.67	0.31
	σ	0.26	0.26	0.26	0.16	0.03
	V,%	9.65	9.68	9.80	9.89	10.34
June	$\overline{X}$	2.56	2.58	2.58	1.61	0.31
	σ	0.16	0.16	0.16	0.10	0.02
	V,%	6.11	6.12	6.16	6.19	6.35
Year	$\overline{X}$	2.44	2.45	2.38	1.47	0.26
	σ	0.12	0.13	0.12	0.08	0.01
	V,%	5.11	5.11	5.12	5.15	5.34

°C/hr = (°F/hr)/1.8

Table 25

Average Warming Rate for Roof System 3A, $^{o}F/hr$

Building Identification		3				
Roofing Layer		Light Colored Gravel		Built-Up Roofing	Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	1.5	3.0
July	$\bar{X}$	4.85	4.90	4.88	3.05	0.58
	σ	0.47	0.47	0.48	0.30	0.06
	V,%	9.61	9.64	9.76	9.85	10.33
August	$\bar{X}$	5.11	5.16	5.07	3.14	0.58
	σ	0.50	0.51	0.51	0.32	0.06
	V,%	9.83	9.88	10.02	10.15	10.80
September	$\bar{X}$	5.25	5.27	5.07	3.11	0.55
	σ	0.39	0.39	0.37	0.23	0.04
	V,%	7.38	7.38	7.39	7.43	7.76
October	$\bar{X}$	4.51	4.51	4.34	2.66	0.47
	σ	0.51	0.51	0.50	0.31	0.06
	V,%	11.40	11.40	11.45	11.49	11.77
November	$\bar{X}$	4.35	4.35	4.19	2.56	0.44
	σ	0.32	0.32	0.31	0.19	0.03
	V,%	7.39	7.41	7.47	7.51	7.70
December	$\bar{X}$	3.86	3.87	3.72	2.27	0.39
	σ	0.37	0.37	0.35	0.21	0.04
	V,%	9.47	9.46	9.44	9.44	9.44
January	$\bar{X}$	3.90	3.91	3.76	2.29	0.39
	σ	0.37	0.37	0.35	0.22	0.04
	V,%	9.43	9.40	9.37	9.38	9.58
February	$\bar{X}$	4.72	4.72	4.53	2.77	0.48
	σ	0.61	0.61	0.59	0.36	0.06
	V,%	12.91	12.91	12.92	12.91	12.76
March	$\bar{X}$	5.57	5.57	5.34	3.27	0.57
	σ	0.48	0.47	0.45	0.28	0.05
	V,%	8.54	8.52	8.49	8.51	8.76
April	$\bar{X}$	5.82	5.85	5.70	3.51	0.63
	σ	0.33	0.34	0.33	0.20	0.03
	V,%	5.74	5.74	5.71	5.68	5.50
May	$\bar{X}$	5.40	5.45	5.39	3.35	0.62
	σ	0.57	0.58	0.58	0.36	0.07
	V,%	10.63	10.65	10.74	10.81	11.20
June	$\bar{X}$	5.16	5.22	5.20	3.25	0.62
	σ	0.33	0.33	0.33	0.21	0.04
	V,%	6.40	6.41	6.42	6.43	6.50
Year	$\bar{X}$	4.87	4.90	4.76	2.94	0.53
	σ	0.25	0.25	0.24	0.15	0.03
	V,%	5.12	5.12	5.13	5.15	5.34

°C/hr = (°F/hr)1.8

Table 26

Average Length of Freezing Period for Roof System 3A, Days

Building Identification		3				
Roofing Layer		Light Colored Gravel		Built-Up Roofing	Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	1.5	3.0
July	$\bar{X}$ σ V,%	---	---	---	---	---
August	$\bar{X}$ σ V,%	---	---	---	---	---
September	$\bar{X}$ σ V,%	---	---	---	---	---
October	$\bar{X}$ σ V,%	---	---	---	---	---
November	$\bar{X}$ σ V,%	0.08 0.09 117.63	0.09 0.09 103.86	0.06 0.07 121.73	---	---
December	$\bar{X}$ σ V,%	0.11 0.03 29.56	0.11 0.04 34.95	0.10 0.04 37.70	---	---
January	$\bar{X}$ σ V,%	0.22 0.10 46.13	0.23 0.10 45.60	0.19 0.10 55.53	---	---
February	$\bar{X}$ σ V,%	0.14 0.04 27.14	0.14 0.04 30.19	0.13 0.04 32.61	---	---
March	$\bar{X}$ σ V,%	0.11 0.02 22.94	0.11 0.02 21.08	0.09 0.02 17.19	---	---
April	$\bar{X}$ σ V,%	0.04 0.04 111.68	0.04 0.04 109.16	0.03 0.04 136.82	---	---
May	$\bar{X}$ σ V,%	---	---	---	---	---
June	$\bar{X}$ σ V,%	---	---	---	---	---
Year	$\bar{X}$ σ V,%	0.15 0.03 18.70	0.15 0.03 20.25	0.13 0.04 27.91		

Table 27

Average Length of Thawing Period for Roof System 3A, Days

Building Identification		3				
Roofing Layer		Light Colored Gravel		Built-Up Roofing	Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	1.5	3.0
July	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
August	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
September	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
October	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
November	$\bar{X}$	[illegible]	16.64	16.66		
	σ	[illegible]	[illegible]	[illegible]	---	---
	V,%	[illegible]	[illegible]	[illegible]		
December	$\bar{X}$	[illegible]	6.13	7.78		
	σ	[illegible]	[illegible]	4.73	---	---
	V,%	[illegible]	88.70	60.82		
January	$\bar{X}$	[illegible]	[illegible]	3.05		
	σ	2.68	2.64	2.51	---	---
	V,%	98.59	95.15	40.29		
February	$\bar{X}$	[illegible]	3.40	3.43		
	σ	[illegible]	0.90	1.69		
	V,%	38.99	37.25	49.32		
March	$\bar{X}$	4.18	4.30	5.55		
	σ	1.84	1.76	1.82	---	---
	V,%	44.02	40.93	32.83		
April	$\bar{X}$	18.47	18.47	18.98		
	σ	10.87	10.87	10.27	---	---
	V,%	58.93	58.84	54.12		
May	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
June	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
Year	$\bar{X}$	9.22	9.60	12.07		
	σ	5.50	5.32	5.98		
	V,%	59.68	55.37	49.53		

Table 28

Average Number of Freeze-Thaw Cycles for Roof System 3A

Building Identification		3				
Roofing Layer		Light Colored Gravel		Built-Up Roofing	Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	1.5	3.0
July	$\overline{X}$ σ V,%	---	---	---	---	---
August	$\overline{X}$ σ V,%	---	---	---	---	---
September	$\overline{X}$ σ V,%	---	---	---	---	---
October	$\overline{X}$ σ V,%	---	---	---	---	---
November	$\overline{X}$ σ V,%	2.20 2.05 93.15	1.80 1.79 99.38	1.80 1.79 99.38	---	---
December	$\overline{X}$ σ V,%	7.40 5.41 73.15	6.80 4.66 68.50	4.20 3.03 72.22	---	---
January	$\overline{X}$ σ V,%	14.80 7.22 48.82	14.00 6.56 46.84	11.80 5.02 42.54	---	---
February	$\overline{X}$ σ V,%	12.00 6.40 53.36	11.60 6.02 51.94	9.00 6.04 67.13	---	---
March	$\overline{X}$ σ V,%	7.60 4.10 53.93	7.20 3.70 51.41	5.20 2.77 53.36	---	---
April	$\overline{X}$ σ V,%	1.20 1.30 108.65	1.20 1.30 108.65	1.00 1.00 100.00	---	---
May	$\overline{X}$ σ V,%	---	---	---	---	---
June	$\overline{X}$ σ V,%	---	---	---	---	---
Year	$\overline{X}$ σ V,%	45.20 15.71 34.75	42.60 14.52 34.08	33.00 10.84 32.85		

Table 29

Average Temperature Above Freezing for Roof System 3B, ^{o}F

Building Identification		3				
Roofing Layer		Light Colored Gravel		Built-Up Roofing	Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	4.5	7.0
July	$\bar{X}$	93.07	92.86	91.83	77.83	72.40
	σ	1.82	1.80	1.70	0.50	0.07
	V,%	1.96	1.94	1.85	0.65	0.10
August	$\bar{X}$	91.26	91.10	90.35	77.64	72.38
	σ	2.25	2.24	2.16	0.71	0.13
	V,%	2.47	2.45	2.39	0.92	0.18
September	$\bar{X}$	83.56	83.54	83.39	75.49	72.20
	σ	2.53	2.53	2.50	0.84	0.12
	V,%	3.03	3.03	2.99	1.12	0.16
October	$\bar{X}$	74.55	74.59	74.68	72.56	71.96
	σ	1.87	1.87	1.84	0.64	0.09
	V,%	2.51	2.51	2.46	0.88	0.13
November	$\bar{X}$	61.85	61.90	61.91	67.78	71.55
	σ	1.73	1.73	1.86	0.80	0.11
	V,%	2.80	2.79	3.00	1.18	0.16
December	$\bar{X}$	58.75	58.39	58.34	65.86	71.39
	σ	1.86	1.68	2.53	1.31	0.16
	V,%	3.17	2.85	4.33	1.99	0.22
January	$\bar{X}$	56.54	56.43	56.44	63.31	71.23
	σ	1.84	1.71	1.57	1.47	0.16
	V,%	3.26	3.03	2.78	2.29	0.23
February	$\bar{X}$	59.54	59.40	58.97	64.67	71.28
	σ	3.85	3.82	3.23	0.90	0.13
	V,%	6.47	6.43	5.47	1.39	0.19
March	$\bar{X}$	64.74	64.71	64.02	67.58	71.52
	σ	2.81	2.83	2.57	0.97	0.13
	V,%	4.35	4.38	4.01	1.43	0.17
April	$\bar{X}$	70.68	70.58	70.19	70.59	71.78
	σ	1.75	1.75	1.53	0.78	0.12
	V,%	2.48	2.47	2.18	1.10	0.17
May	$\bar{X}$	79.39	79.20	78.38	73.30	72.01
	σ	2.07	2.05	1.96	0.62	0.07
	V,%	2.61	2.59	2.50	0.84	0.10
June	$\bar{X}$	88.49	88.26	87.19	76.10	72.25
	σ	1.95	1.94	1.88	0.63	0.09
	V,%	2.20	2.19	2.16	0.82	0.12
Year	$\bar{X}$	74.58	74.49	73.88	71.15	71.83
	σ	0.81	0.78	0.67	0.31	0.06
	V,%	1.08	1.05	0.91	0.44	0.09

°C = (°F - 32)/1.8

Table 30

Average Temperature Below Freezing for Roof System 3B, °F

Building Identification		3				
Roofing Layer		Light Colored Gravel		Built-Up Roofing	Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	4.5	7.0
July	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
August	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
September	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
October	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
November	$\overline{X}$	26.66	26.64	25.03		
	σ	4.02	4.08	2.77	---	---
	V,%	15.06	15.30	11.08		
December	$\overline{X}$	27.18	27.24	26.80		
	σ	1.41	1.51	1.43	---	---
	V,%	5.20	5.54	5.34		
January	$\overline{X}$	23.84	23.73	24.03		
	σ	3.60	3.51	3.48	---	---
	V,%	15.11	14.78	14.48		
February	$\overline{X}$	24.96	24.80	24.57		
	σ	1.55	1.66	2.23	---	---
	V,%	6.19	6.68	9.05		
March	$\overline{X}$	26.89	26.78	26.02		
	σ	2.28	2.10	1.84	---	---
	V,%	8.48	7.83	7.06		
April	$\overline{X}$	27.56	27.25	26.37		
	σ	2.42	2.48	1.57	---	---
	V,%	8.77	9.09	5.95		
May	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
June	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
Year	$\overline{X}$	25.56	25.45	25.05		
	σ	0.99	0.89	1.17	---	---
	V,%	3.89	3.50	4.65		

°C = (°F - 32)/1.8

Table 31

Average Cooling Rate for Roof System 3B, °F/hr

Building Identification		3				
Roofing Layer		Light Colored Gravel		Built-Up Roofing	Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	4.5	7.0
July	$\overline{X}$	2.48	2.52	2.61	0.89	0.06
	σ	0.23	0.23	0.24	0.09	0.01
	V,%	9.13	9.16	9.25	9.77	10.40
August	$\overline{X}$	2.65	2.68	2.75	0.90	0.06
	σ	0.24	0.25	0.26	0.09	0.01
	V,%	9.11	9.15	9.29	10.01	10.92
September	$\overline{X}$	2.69	2.70	2.71	0.85	0.05
	σ	0.19	0.19	0.19	0.06	0.00
	V,%	7.01	7.02	7.06	7.46	8.10
October	$\overline{X}$	2.31	2.32	2.32	0.72	0.04
	σ	0.26	0.26	0.26	0.08	0.01
	V,%	11.19	11.19	11.24	11.60	12.08
November	$\overline{X}$	2.22	2.23	2.24	0.67	0.04
	σ	0.17	0.17	0.17	0.05	0.00
	V,%	7.44	7.46	7.49	7.61	7.74
December	$\overline{X}$	1.94	1.94	1.95	0.58	0.03
	σ	0.21	0.21	0.21	0.06	0.00
	V,%	10.92	10.91	10.85	10.83	10.96
January	$\overline{X}$	1.98	1.99	1.99	0.59	0.03
	σ	0.17	0.17	0.17	0.05	0.00
	V,%	8.58	8.59	8.63	8.93	9.02
February	$\overline{X}$	2.39	2.39	2.39	0.72	0.04
	σ	0.27	0.27	0.27	0.08	0.00
	V,%	11.12	11.13	11.16	11.07	10.53
March	$\overline{X}$	2.78	2.79	2.79	0.86	0.05
	σ	0.26	0.26	0.26	0.08	0.01
	V,%	9.47	9.47	9.47	9.60	9.71
April	$\overline{X}$	2.95	2.98	3.02	0.95	0.06
	σ	0.19	0.19	0.19	0.06	0.00
	V,%	6.54	6.53	6.43	6.22	6.06
May	$\overline{X}$	2.77	2.81	2.90	0.96	0.06
	σ	0.24	0.25	0.26	0.09	0.01
	V,%	8.75	8.78	8.89	9.37	9.89
June	$\overline{X}$	2.62	2.66	2.76	0.95	0.06
	σ	0.15	0.15	0.15	0.05	0.00
	V,%	5.54	5.55	5.59	5.73	5.92
Year	$\overline{X}$	2.48	2.50	2.53	0.80	0.05
	σ	0.12	0.12	0.12	0.04	0.00
	V,%	4.92	4.92	4.92	5.08	5.35

°C/hr = (°F/hr)/1.8

Table 32

Average Warming Rate for Roof System 3B, $^{o}F/hr$

Building Identification		3				
Roofing Layer		Light Colored Gravel		Built-Up Roofing	Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	4.5	7.0
July	$\overline{X}$	4.98	5.04	5.23	1.78	0.12
	σ	0.43	0.44	0.46	0.17	0.01
	V,%	8.62	8.64	8.75	9.27	9.84
August	$\overline{X}$	5.28	5.34	5.48	1.78	0.12
	σ	0.47	0.48	0.50	0.17	0.01
	V,%	8.87	8.91	9.06	9.80	10.72
September	$\overline{X}$	5.33	5.35	5.37	1.68	0.11
	σ	0.38	0.38	0.39	0.13	0.01
	V,%	7.18	7.19	7.22	7.59	8.18
October	$\overline{X}$	4.58	4.60	4.60	1.42	0.09
	σ	0.48	0.48	0.48	0.15	0.01
	V,%	10.43	10.43	10.48	10.83	11.28
November	$\overline{X}$	4.38	4.40	4.40	1.32	0.08
	σ	0.35	0.35	0.35	0.11	0.01
	V,%	7.94	7.95	7.97	8.06	8.33
December	$\overline{X}$	3.88	3.89	3.89	1.15	0.06
	σ	0.39	0.40	0.39	0.12	0.01
	V,%	10.16	10.16	10.11	10.02	9.98
January	$\overline{X}$	3.96	3.97	3.98	1.18	0.07
	σ	0.36	0.36	0.36	0.11	0.01
	V,%	9.02	9.02	9.04	9.31	9.55
February	$\overline{X}$	4.82	4.84	4.83	1.46	0.09
	σ	0.56	0.56	0.56	0.17	0.01
	V,%	11.65	11.66	11.68	11.62	11.24
March	$\overline{X}$	5.57	5.59	5.58	1.71	0.11
	σ	0.55	0.55	0.55	0.17	0.01
	V,%	9.86	9.86	9.87	10.09	10.35
April	$\overline{X}$	5.96	6.01	6.10	1.92	0.12
	σ	0.31	0.31	0.31	0.09	0.01
	V,%	5.13	5.14	5.07	4.86	4.70
May	$\overline{X}$	5.58	5.65	5.83	1.94	0.13
	σ	0.54	0.54	0.57	0.20	0.01
	V,%	9.60	9.61	9.69	10.11	10.58
June	$\overline{X}$	5.29	5.36	5.57	1.92	0.13
	σ	0.31	0.31	0.32	0.11	0.01
	V,%	5.82	5.82	5.83	5.88	6.01
Year	$\overline{X}$	4.96	5.00	5.07	1.61	0.10
	σ	0.24	0.25	0.25	0.08	0.01
	V,%	4.93	4.93	4.93	5.07	5.21

°C/hr = (°F/hr)/1.8

Table 33

Average Length of Freezing Period for Roof System 3B, Days

Building Identification		3				
Roofing Layer		Light Colored Gravel		Built-Up Roofing	Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	4.5	7.0
July	$\overline{X}$ σ V,%	---	---	---	---	---
August	$\overline{X}$ σ V,%	---	---	---	---	---
September	$\overline{X}$ σ V,%	---	---	---	---	---
October	$\overline{X}$ σ V,%	---	---	---	---	---
November	$\overline{X}$ σ V,%	0.10 0.09 90.00	0.11 0.09 81.82	0.07 0.07 100.00	---	---
December	$\overline{X}$ σ V,%	0.13 0.05 41.82	0.13 0.04 30.77	0.12 0.03 25.00	---	---
January	$\overline{X}$ σ V,%	0.24 0.11 44.62	0.25 0.10 40.00	0.21 0.11 52.38	---	---
February	$\overline{X}$ σ V,%	0.16 0.03 16.49	0.16 0.03 18.75	0.15 0.04 2.67	---	---
March	$\overline{X}$ σ V,%	0.10 0.04 45.35	0.10 0.04 40.00	0.09 0.03 33.33	---	---
April	$\overline{X}$ σ V,%	0.04 0.05 129.42	0.04 0.05 125.00	0.03 0.04 133.33	---	---
May	$\overline{X}$ σ V,%	---	---	---	---	---
June	$\overline{X}$ σ V,%	---	---	---	---	---
Year	$\overline{X}$ σ V,%	0.16 0.02 12.76	0.16 0.02 12.50	0.14 0.03 21.43		

Table 34

Average Length of Thawing Period for Roof System 3B, Days

Building Identification		3				
Roofing Layer		Light Colored Gravel		Built-Up Roofing	Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	4.5	7.0
July	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
August	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
September	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
October	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
November	$\bar{X}$	12.34	13.22	14.01		
	σ	9.30	8.96	9.04	---	---
	V,%	75.39	67.78	64.52		
December	$\bar{X}$	5.50	5.63	6.65		
	σ	5.16	5.11	4.52	---	---
	V,%	93.88	90.76	67.97		
January	$\bar{X}$	2.55	2.62	2.77		
	σ	2.43	2.41	2.38	---	---
	V,%	95.30	91.98	85.92		
February	$\bar{X}$	2.14	2.24	3.16		
	σ	0.90	0.94	1.70	---	---
	V,%	42.03	41.96	53.79		
March	$\bar{X}$	4.37	4.49	5.66		
	σ	2.19	1.95	2.06	---	---
	V,%	50.20	43.43	36.39		
April	$\bar{X}$	19.56	19.45	19.74		
	σ	11.48	11.25	11.19	---	---
	V,%	58.69	57.79	56.69		
May	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
June	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
Year	$\bar{X}$	8.54	8.91	11.41		
	σ	4.42	4.20	4.81		
	V,%	51.78	47.14	42.16		

Table 35

Average Number of Freeze-Thaw Cycles for Roof System 3B

Building Identification		3				
Roofing Layer		Light Colored Gravel		Built-Up Roofing	Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	4.5	7.0
July	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
August	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
September	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
October	$\bar{X}$					
	σ	---	---	---	---	---
November	$\bar{X}$	2.33	2.33	1.83	0.00	0.00
	σ	1.63	1.63	1.60		
	V,%	69.99	69.99	87.39		
Decemeber	$\bar{X}$	8.17	8.33	6.50	0.00	0.00
	σ	5.60	5.72	4.93		
	V,%	68.58	68.59	75.84		
January	$\bar{X}$	15.00	14.67	14.00	0.00	0.00
	σ	6.93	6.83	6.23		
	V,%	46.19	46.58	44.49		
February	$\bar{X}$	13.00	12.67	11.50	0.00	0.00
	σ	5.87	5.72	5.47		
	V,%	45.12	45.12	47.55		
March	$\bar{X}$	7.67	7.50	6.00	0.00	0.00
	σ	4.68	4.89	3.85		
	V,%	60.99	65.18	64.12		
April	$\bar{X}$	1.17	1.17	1.00	0.00	0.00
	σ	1.33	1.33	1.26		
	V,%	113.93	113.93	126.49		
May	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
June	$\bar{X}$					
	σ	---	---	---	---	---
	V,%					
Year	$\bar{X}$	47.33	46.67	40.83	0.00	0.00
	σ	15.82	16.27	14.19		
	V,%	33.42	34.86	34.75		

Table 36

Average Temperature Above Freezing for Roof System 4A, °F

Building Identification		4			
Roofing Layer		GAF Mineral Shield		Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	2.5
July	$\overline{X}$	93.59	91.67	83.81	73.98
	σ	1.95	1.76	1.06	0.19
	V,%	2.08	1.92	1.26	0.25
August	$\overline{X}$	91.74	90.04	82.92	73.92
	σ	2.34	2.15	1.31	0.25
	V,%	2.55	2.39	1.58	0.34
September	$\overline{X}$	83.79	83.11	78.82	73.24
	σ	2.51	2.37	1.47	0.29
	V,%	2.99	2.85	1.86	0.39
October	$\overline{X}$	75.02	75.03	73.87	72.32
	σ	1.83	1.73	1.07	0.22
	V,%	2.44	2.30	1.44	0.30
November	$\overline{X}$	62.54	63.05	65.95	70.80
	σ	1.91	1.67	1.34	0.28
	V,%	3.05	2.64	2.04	0.39
December	$\overline{X}$	58.47	58.50	62.71	70.19
	σ	2.79	3.07	2.24	0.43
	V,%	4.77	5.25	3.57	0.62
January	$\overline{X}$	56.19	55.85	59.42	69.57
	σ	1.98	2.44	2.50	0.49
	V,%	3.53	4.36	4.21	0.70
February	$\overline{X}$	58.66	58.65	60.76	69.82
	σ	3.03	2.97	1.58	0.31
	V,%	5.16	5.06	2.60	0.44
March	$\overline{X}$	64.00	64.14	65.75	70.76
	σ	2.07	1.94	1.68	0.33
	V,%	3.23	3.02	2.55	0.46
April	$\overline{X}$	71.84	71.35	71.24	71.75
	σ	1.69	1.60	1.28	0.26
	V,%	2.36	2.24	1.79	0.37
May	$\overline{X}$	81.35	80.05	76.66	72.64
	σ	2.10	1.91	1.16	0.21
	V,%	2.58	2.39	1.51	0.29
June	$\overline{X}$	90.51	88.69	81.92	73.57
	σ	1.95	1.82	1.12	0.22
	V,%	2.16	2.06	1.36	0.30
Year	$\overline{X}$	74.85	74.00	72.05	71.89
	σ	0.54	0.44	0.51	0.14
	V,%	0.72	0.60	0.70	0.20

°C = (°F - 32)/1.8

Table 37

Average Temperature Below Freezing for Roof System 4A, ^{o}F

Building Identification		4			
Roofing Layer		GAF Mineral Shield		Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	2.5
July	$\bar{X}$				
	σ	---	---	---	---
	V,%				
August	$\bar{X}$				
	σ	---	---	---	---
	V,%				
September	$\bar{X}$				
	σ	---	---	---	---
	V,%				
October	$\bar{X}$				
	σ	---	---	---	---
	V,%				
November	$\bar{X}$	28.02	29.40		
	σ	2.54	0.63	---	---
	V,%	9.08	2.17		
December	$\bar{X}$	28.16	29.14		
	σ	1.84	0.83	---	---
	V,%	6.54	2.86		
January	$\bar{X}$	26.33	27.56		
	σ	3.23	2.67	---	---
	V,%	12.26	10.44		
February	$\bar{X}$	26.74	27.73		
	σ	1.45	2.59	---	---
	V,%	5.43	9.41		
March	$\bar{X}$	27.64	29.05		
	σ	0.96	2.09	---	---
	V,%	3.48	7.19		
April	$\bar{X}$	28.82	29.57		
	σ	0.16	0.19	---	---
	V,%	0.56	0.65		
May	$\bar{X}$				
	σ	---	---	---	---
	V,%				
June	$\bar{X}$				
	σ	---	---	---	---
	V,%				
Year	$\bar{X}$	27.17	28.16		
	σ	1.08	2.92		
	V,%	3.96	10.53		

$^{\circ}C = (^{\circ}F - 32)/1.8$

Table 38

Average Cooling Rate for Roof System 4A, °F/hr

Building Identification		4			
Roofing Layer		GAF Mineral Shield		Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	2.5
July	$\bar{X}$	2.13	2.17	1.38	0.28
	σ	0.19	0.20	0.13	0.03
	V,%	9.07	9.16	9.25	9.65
August	$\bar{X}$	2.32	2.34	1.47	0.29
	σ	0.21	0.21	0.14	0.03
	V,%	8.95	9.10	9.21	9.71
September	$\bar{X}$	2.43	2.38	1.48	0.27
	σ	0.17	0.17	0.10	0.02
	V,%	6.99	7.01	7.05	7.28
October	$\bar{X}$	2.11	2.05	1.26	0.23
	σ	0.24	0.23	0.14	0.03
	V,%	11.28	11.28	11.31	11.49
November	$\bar{X}$	2.03	1.99	1.23	0.22
	σ	0.15	0.15	0.09	0.02
	V,%	7.49	7.52	7.53	7.55
December	$\bar{X}$	1.78	1.74	1.08	0.19
	σ	0.20	0.19	0.12	0.02
	V,%	11.05	11.02	11.02	11.03
January	$\bar{X}$	1.82	1.78	1.10	0.20
	σ	0.15	0.15	0.09	0.02
	V,%	8.52	8.53	8.59	9.01
February	$\bar{X}$	2.18	2.13	1.31	0.24
	σ	0.24	0.24	0.15	0.03
	V,%	11.19	11.20	11.19	11.15
March	$\bar{X}$	2.54	2.47	1.53	0.28
	σ	0.24	0.24	0.15	0.03
	V,%	9.59	9.59	9.61	9.73
April	$\bar{X}$	2.62	2.62	1.64	0.31
	σ	0.18	0.18	0.11	0.02
	V,%	6.82	6.74	6.70	6.51
May	$\bar{X}$	2.40	2.44	1.54	0.31
	σ	0.21	0.21	0.14	0.03
	V,%	8.56	8.69	8.79	9.20
June	$\bar{X}$	2.24	2.28	1.45	0.30
	σ	0.12	0.13	0.08	0.02
	V,%	5.53	5.58	5.60	5.72
Year	$\bar{X}$	2.22	2.20	1.37	0.26
	σ	0.11	0.11	0.07	0.01
	V,%	4.96	4.94	4.95	5.06

°C/hr = (°F/hr)/1.8

Table 39

Average Warming Rate for Roof System 4A, °F/hr

Building Identification		4			
Roofing Layer		GAF Mineral Shield		Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	2.5
July	$\bar{X}$	4.27	4.35	2.77	0.56
	σ	0.36	0.38	0.24	0.05
	V,%	8.50	8.62	8.71	9.13
August	$\bar{X}$	4.62	4.67	2.94	0.57
	σ	0.40	0.41	0.26	0.05
	V,%	8.68	8.85	8.96	9.48
September	$\bar{X}$	4.82	4.72	2.92	0.54
	σ	0.34	0.34	0.21	0.04
	V,%	7.16	7.18	7.21	7.42
October	$\bar{X}$	4.17	4.05	2.51	0.46
	σ	0.44	0.42	0.26	0.05
	V,%	10.47	10.48	10.51	10.68
November	$\bar{X}$	4.00	3.91	2.41	0.44
	σ	0.32	0.31	0.19	0.04
	V,%	8.02	8.04	8.04	8.03
December	$\bar{X}$	3.56	3.49	2.15	0.39
	σ	0.37	0.36	0.22	0.04
	V,%	10.27	10.27	10.27	10.27
January	$\bar{X}$	3.63	3.54	2.19	0.40
	σ	0.33	0.32	0.20	0.04
	V,%	9.02	9.00	9.05	9.43
February	$\bar{X}$	4.41	4.30	2.65	0.48
	σ	0.52	0.50	0.31	0.06
	V,%	11.75	11.75	11.74	11.71
March	$\bar{X}$	5.08	4.94	3.05	0.56
	σ	0.51	0.49	0.31	0.06
	V,%	9.97	9.98	10.00	10.17
April	$\bar{X}$	5.30	5.30	3.31	0.62
	σ	0.28	0.28	0.18	0.03
	V,%	5.33	5.32	5.29	5.13
May	$\bar{X}$	4.83	4.91	3.10	0.62
	σ	0.46	0.47	0.30	0.06
	V,%	9.51	9.58	9.65	9.98
June	$\bar{X}$	4.52	4.61	2.94	0.60
	σ	0.27	0.27	0.17	0.04
	V,%	5.87	5.88	5.88	5.91
Year	$\bar{X}$	4.43	4.40	2.74	0.52
	σ	0.22	0.22	0.14	0.03
	V,%	4.96	4.95	4.95	5.06

°C/hr = (°F/hr)1.8

Table 40

Average Length of Freezing Period for Roof System 4A, Days

Building Identification		4			
Roofing Layer		GAF Mineral Shield		Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	2.5
July	$\overline{X}$	---	---	---	---
	σ				
	V,%				
August	$\overline{X}$				
	σ				
	V,%				
September	$\overline{X}$				
	σ				
	V,%				
October	$\overline{X}$				
	σ				
	V,%				
November	$\overline{X}$	0.07			
	σ	0.07	---	---	---
	V,%	100.00			
December	$\overline{X}$	0.11			
	σ	0.05	---	---	---
	V,%	48.10			
January	$\overline{X}$	0.18			
	σ	0.10	---	---	---
	V,%	56.37			
February	$\overline{X}$	0.13			
	σ	0.04	---	---	---
	V,%	28.64			
March	$\overline{X}$	0.07			
	σ	0.04			
	V,%	60.44			
April	$\overline{X}$	0.02			
	σ	0.03	---	---	---
	V,%	168.57			
May	$\overline{X}$				
	σ				
	V,%				
June	$\overline{X}$				
	σ				
	V,%				
Year	$\overline{X}$	0.13			
	σ	0.03			
	V,%	20.89			

Table 41

Average Length of Thawing Period for Roof System 4A, Days

Building Identification		4			
Roofing Layer		GAF Mineral Shield		Urethane Board	Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.0	2.5
July	$\bar{X}$				
	σ				
	V,%				
August	$\bar{X}$				
	σ				
	V,%				
September	$\bar{X}$				
	σ				
	V,%				
October	$\bar{X}$				
	σ				
	V,%				
November	$\bar{X}$	15.54			
	σ	11.31			
	V,%	72.78			
December	$\bar{X}$	7.28			
	σ	4.98	---	---	---
	V,%	68.38			
January	$\bar{X}$	2.83			
	σ	2.32	---	---	---
	V,%	81.98			
February	$\bar{X}$	2.81			
	σ	1.27	---	---	---
	V,%	45.09			
March	$\bar{X}$	9.46			
	σ	10.69	---	---	---
	V,%	113.03			
April	$\bar{X}$	24.15			
	σ	9.19	---	---	---
	V,%	38.08			
May	$\bar{X}$				
	σ				
	V,%				
June	$\bar{X}$				
	σ				
	V,%				
Year	$\bar{X}$	11.22			
	σ	5.30			
	V,%	47.21			

Table 42

Average Number of Freeze-Thaw Cycles for Roof System 4A

Building Identification		4				
Roofing Layer		GAF Mineral Shield		Urethane Board	Gypsum Plank	
Depth in Section (in.)		0.0	0.5	1.0	2.5	
July	$\overline{X}$	---	---	---	---	---
	σ					
	V,%					
August	$\overline{X}$	---	---	---	---	---
	σ					
	V,%					
September	$\overline{X}$	---	---	---	---	---
	σ					
	V,%					
October	$\overline{X}$	---	---	---	---	---
	σ					
	V,%					
November	$\overline{X}$	1.83	1.50	0.00	0.00	0.00
	σ	1.60	1.38			
	V,%	87.39	91.89			
December	$\overline{X}$	5.33	3.33	0.00	0.00	0.00
	σ	4.23	2.66			
	V,%	79.25	79.75			
January	$\overline{X}$	12.67	9.50	0.00	0.00	0.00
	σ	5.32	3.94			
	V,%	41.97	41.44			
February	$\overline{X}$	10.33	8.50	0.00	0.00	0.00
	σ	5.47	5.47			
	V,%	52.89	64.33			
March	$\overline{X}$	4.83	4.00	0.00	0.00	0.00
	σ	3.66	2.90			
	V,%	75.64	72.46			
April	$\overline{X}$	0.50	0.50	0.00	0.00	0.00
	σ	0.84	0.84			
	V,%	167.33	167.33			
May	$\overline{X}$	---	---	---	---	---
	σ					
	V,%					
June	$\overline{X}$	---	---	---	---	---
	σ					
	V,%					
Year	$\overline{X}$	35.50	27.33	0.00	0.00	0.00
	σ	[illegible]69	8.38			
	V,%	32.93	30.67			

Table 43

Average Temperature Above Freezing for Roof System 4B, °F

Building Identification		4				
Roofing Layer		GAF Mineral Shield		Urethane Board		Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.5	4.0	6.5
July	$\bar{X}$	94.05	92.88	87.85	78.07	72.44
	σ	1.98	1.86	1.40	0.55	0.08
	V,%	2.10	2.00	1.60	0.70	0.12
August	$\bar{X}$	92.19	91.20	86.92	77.92	72.42
	σ	2.39	2.29	1.81	0.75	0.12
	V,%	2.60	2.51	2.09	0.96	0.16
September	$\bar{X}$	84.08	83.87	81.56	75.82	72.24
	σ	2.57	2.54	2.06	0.87	0.13
	V,%	3.05	3.02	2.53	1.15	0.18
October	$\bar{X}$	75.09	75.24	74.65	72.94	72.00
	σ	1.88	1.85	1.50	0.64	0.11
	V,%	2.51	2.46	2.01	0.88	0.15
November	$\bar{X}$	62.[illegible]	62.69	63.56	68.22	71.60
	σ	1.81	1.7[illegible]	1.8[illegible]	[illegible]	0.09
	V,%	2.91	2.[illegible]4	2.84	1.[illegible]	0.12
December	$\bar{X}$	58.76	59.16	59.04	66.31	71.45
	σ	2.75	2.78	3.13	1.33	0.15
	V,%	4.68	4.70	5.29	2.01	0.21
January	$\bar{X}$	56.39	56.73	55.30	64.38	71.29
	σ	1.82	1.67	3.13	1.47	0.16
	V,%	3.22	2.95	5.66	2.29	0.22
February	$\bar{X}$	58.92	59.28	57.22	65.15	71.34
	σ	3.32	3.54	2.30	0.91	0.12
	V,%	5.63	5.98	4.02	1.40	0.17
March	$\bar{X}$	64.17	64.47	63.36	68.08	71.58
	σ	1.96	1.92	2.37	0.99	0.13
	V,%	3.05	2.98	3.74	1.46	0.18
April	$\bar{X}$	71.89	71.47	70.64	71.14	71.84
	σ	1.58	1.68	1.81	0.78	0.08
	V,%	2.19	2.35	2.56	1.10	0.12
May	$\bar{X}$	81.49	80.46	77.83	73.92	72.08
	σ	2.14	2.03	1.56	0.63	0.08
	V,%	2.62	2.52	2.01	0.85	0.12
June	$\bar{X}$	90.87	89.65	85.05	76.79	72.32
	σ	2.00	1.94	1.54	0.63	0.08
	V,%	2.20	2.16	1.81	0.82	0.11
Year	$\bar{X}$	75.17	74.84	72.11	71.60	71.89
	σ	0.70	0.60	0.59	0.32	0.09
	V,%	0.93	0.80	0.82	0.44	0.13

°C = (°F - 32)/1.8

Table 44

Average Temperature Below Freezing for Roof System 4B, ^{o}F

Building Identification		4				
Roofing Layer		GAF Mineral Shield		Urethane Board		Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.5	4.0	6.5
July	$\overline{X}$ σ V,%	---	---	---	---	---
August	$\overline{X}$ σ V,%	---	---	---	---	---
September	$\overline{X}$ σ V,%	---	---	---	---	---
October	$\overline{X}$ σ V,%	---	---	---	---	---
November	$\overline{X}$ σ V,%	27.12 2.82 10.39	27.15 2.85 10.49	30.63 0.00 0.00	---	---
December	$\overline{X}$ σ V,%	27.92 1.16 4.16	29.24 1.00 3.55	31.04 0.88 2.83	---	---
January	$\overline{X}$ σ V,%	25.42 3.30 12.97	25.64 3.22 12.56	28.73 1.54 5.36	---	---
February	$\overline{X}$ σ V,%	26.12 1.54 5.88	26.17 1.25 4.78	29.89 0.92 3.08	---	---
March	$\overline{X}$ σ V,%	27.58 1.72 6.22	27.76 1.74 6.28	30.76 1.50 4.89	---	---
April	$\overline{X}$ σ V,%	28.41 1.29 4.54	28.56 2.34 8.18	---	---	---
May	$\overline{X}$ σ V,%	---	---	---	---	---
June	$\overline{X}$ σ V,%	---	---	---	---	---
Year	$\overline{X}$ σ V,%	26.51 1.07 4.03	26.63 1.04 3.91	29.78 1.28 4.31		

°C = (°F - 32)/1.8

Table 45

Average Cooling Rate for Roof System 4B, $^{o}F/hr$

Building Identification		4				
Roofing Layer		GAF Mineral Shield		Urethane Board		Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.5	4.0	6.5
July	$\overline{X}$	2.20	2.34	2.04	0.87	0.06
	σ	0.20	0.21	0.19	0.08	0.01
	V,%	9.04	9.15	9.34	9.66	10.23
August	$\overline{X}$	2.39	2.52	2.14	0.88	0.06
	σ	0.21	0.23	0.20	0.09	0.01
	V,%	8.89	9.05	9.30	9.71	10.55
September	$\overline{X}$	2.50	2.55	2.09	0.84	0.06
	σ	0.17	0.18	0.15	0.06	0.00
	V,%	6.96	6.99	7.07	7.29	7.85
October	$\overline{X}$	2.16	2.19	1.79	0.71	0.05
	σ	0.24	0.25	0.20	0.08	0.01
	V,%	11.23	11.23	11.30	11.47	11.84
November	$\overline{X}$	2.09	2.13	1.74	0.68	0.04
	σ	0.16	0.16	0.13	0.05	0.00
	V,%	7.45	7.49	7.52	7.51	7.44
December	$\overline{X}$	1.83	1.87	1.52	0.60	0.04
	σ	0.20	0.21	0.17	0.07	0.00
	V,%	11.07	11.04	11.02	11.06	11.37
January	$\overline{X}$	1.87	1.90	1.56	0.61	0.04
	σ	0.16	0.16	0.14	0.06	0.00
	V,%	8.52	8.54	8.69	9.06	9.84
February	$\overline{X}$	2.25	2.28	1.86	0.74	0.05
	σ	0.25	0.26	0.21	0.08	0.01
	V,%	11.20	11.21	11.20	11.16	11.11
March	$\overline{X}$	2.61	2.65	2.16	0.86	0.06
	σ	0.25	0.25	0.21	0.08	0.01
	V,%	9.58	9.59	9.62	9.75	10.08
April	$\overline{X}$	2.70	2.81	2.34	0.94	0.06
	σ	0.18	0.19	0.16	0.06	0.00
	V,%	6.81	6.72	6.62	6.47	6.20
May	$\overline{X}$	2.47	2.63	2.26	0.95	0.06
	σ	0.21	0.23	0.20	0.09	0.01
	V,%	8.57	8.71	8.93	9.23	9.63
June	$\overline{X}$	2.31	2.46	2.16	0.93	0.07
	σ	0.13	0.14	0.12	0.05	0.00
	V,%	5.52	5.57	5.63	5.71	5.83
Year	$\overline{X}$	2.28	2.36	1.97	0.80	0.05
	σ	0.11	0.12	0.10	0.04	0.00
	V,%	4.95	4.94	4.97	5.07	5.40

°C/hr = (°F/hr)/1.8

Table 46

Average Warming Rate for Roof System 4B, °F/hr

Building Identification		4				
Roofing Layer		GAF Mineral Shield		Urethane Board		Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.5	4.0	6.5
July	$\overline{X}$	4.40	4.69	4.09	1.74	0.12
	σ	0.37	0.40	0.36	0.16	0.01
	V,%	8.48	8.61	8.82	9.14	9.66
August	$\overline{X}$	4.75	5.02	4.26	1.75	0.12
	σ	0.41	0.44	0.39	0.17	0.01
	V,%	8.62	8.80	9.06	9.48	10.32
September	$\overline{X}$	4.95	5.05	4.14	1.66	0.11
	σ	0.35	0.36	0.30	0.12	0.01
	V,%	7.14	7.16	7.23	7.43	7.97
October	$\overline{X}$	4.28	4.34	3.55	1.42	0.09
	σ	0.45	0.45	0.37	0.15	0.01
	V,%	10.42	10.43	10.50	10.66	10.98
November	$\overline{X}$	4.11	4.19	3.42	1.34	0.08
	σ	0.33	0.34	0.27	0.11	0.01
	V,%	7.99	8.01	8.02	7.99	8.00
December	$\overline{X}$	3.67	3.74	3.05	1.19	0.07
	σ	0.38	0.38	0.31	0.12	0.01
	V,%	10.29	10.29	10.28	10.29	10.39
January	$\overline{X}$	3.73	3.80	3.10	1.22	0.07
	σ	0.34	0.34	0.28	0.12	0.01
	V,%	9.02	9.01	9.13	9.49	10.40
February	$\overline{X}$	4.54	4.61	3.76	1.49	0.09
	σ	0.53	0.54	0.44	0.17	0.01
	V,%	11.76	11.76	11.74	11.72	11.72
March	$\overline{X}$	5.23	5.29	4.32	1.72	0.11
	σ	0.52	0.53	0.43	0.18	0.01
	V,%	9.97	9.98	10.03	10.19	10.62
April	$\overline{X}$	5.45	5.69	4.73	1.91	0.13
	σ	0.29	0.30	0.25	0.10	0.01
	V,%	5.31	5.29	5.24	5.08	4.76
May	$\overline{X}$	4.98	5.29	4.55	1.90	0.13
	σ	0.47	0.51	0.44	0.19	0.01
	V,%	9.51	9.59	9.75	10.00	10.43
June	$\overline{X}$	4.66	4.98	4.36	1.87	0.13
	σ	0.27	0.29	0.26	0.11	0.01
	V,%	5.86	5.87	5.88	5.90	5.97
Year	$\overline{X}$	4.56	4.72	3.95	1.60	0.11
	σ	0.23	0.23	0.20	0.08	0.01
	V,%	4.96	4.95	4.97	5.07	5.27

°C/hr = (°F/hr)/1.8

Table 47

Average Length of Freezing Period for Roof System 4B, Days

Building Identification		4				
Roofing Layer		GAF Mineral Shield		Urethane Board		Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.5	4.0	6.5
July	$\overline{X}$ σ V,%	---	---	---	---	---
August	$\overline{X}$ σ V,%	---	---	---	---	---
September	$\overline{X}$ σ V,%	---	---	---	---	---
October	$\overline{X}$ σ V,%	---	---	---	---	---
November	$\overline{X}$ σ V,%	0.08 0.08 100.00				
December	$\overline{X}$ σ V,%	0.11 0.03 24.17	---	---	---	---
January	$\overline{X}$ σ V,%	0.20 0.10 50.00	---	---	---	---
February	$\overline{X}$ σ V,%	0.14 0.04 25.02	---	---	---	---
March	$\overline{X}$ σ V,%	0.09 0.03 38.76	---	---	---	---
April	$\overline{X}$ σ V,%	0.02 0.04 181.94	---	---	---	---
May	$\overline{X}$ σ V,%	---	---	---	---	---
June	$\overline{X}$ σ V,%	---	---	---	---	---
Year	$\overline{X}$ σ V,%	0.15 0.03 19.23				

Table 48

Average Length of Thawing Period for Roof System 4B, Days

Building Identification		4				
Roofing Layer		GAF Mineral Shield		Urethane Board		Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.5	4.0	6.5
July	$\overline{X}$ σ V,%	---	---	---	---	---
August	$\overline{X}$ σ V,%	---	---	---	---	---
September	$\overline{X}$ σ V,%	---	---	---	---	---
October	$\overline{X}$ σ V,%	---	---	---	---	---
November	$\overline{X}$ σ V,%	15.11 11.61 76.82	---	---	---	---
December	$\overline{X}$ σ V,%	6.29 4.99 79.41	---	---	---	---
January	$\overline{X}$ σ V,%	2.70 2.37 88.13	---	---	---	---
February	$\overline{X}$ σ V,%	2.48 1.03 41.40	---	---	---	---
March	$\overline{X}$ σ V,%	6.54 4.62 70.71	---	---	---	---
April	$\overline{X}$ σ V,%	23.32 10.35 44.39	---	---	---	---
May	$\overline{X}$ σ V,%	---	---	---	---	---
June	$\overline{X}$ σ V,%	---	---	---	---	---
Year	$\overline{X}$ σ V,%	10.14 5.19 51.19				

Table 49

Average Number of Freeze-Thaw Cycles for Roof System 4B

Building Identification		4				
Roofing Layer		GAF Mineral Shield		Urethane Board		Gypsum Plank
Depth in Section (in.)		0.0	0.5	1.5	4.0	6.5
July	$\overline{X}$					
	σ	---	---	---	---	
	V,%					
August	$\overline{X}$					
	σ	---	---	---	---	
	V,%					
September	$\overline{X}$					
	σ	---	---	---	---	
	V,%					
October	$\overline{X}$					
	σ	---	---	---	---	
	V,%					
November	$\overline{X}$	2.00	2.00	0.17	0.00	0.00
	σ	1.67	1.67	0.41		
	V,%	83.67	83.67	244.95		
December	$\overline{X}$	6.67	6.67	0.33	0.00	0.00
	σ	5.16	4.84	0.52		
	V,%	77.46	77.66	154.92		
January	$\overline{X}$	13.83	13.50	2.33	0.00	0.00
	σ	6.34	6.06	3.88		
	V,%	45.81	44.87	166.35		
February	$\overline{X}$	11.33	11.00	2.17	0.00	0.00
	σ	5.39	5.76	1.47		
	V,%	47.57	52.38	67.94		
March	$\overline{X}$	5.50	5.50	0.33	0.00	0.00
	σ	4.04	3.73	0.52		
	V,%	73.41	67.79	154.92		
April	$\overline{X}$	0.67	0.83	0.00	0.00	0.00
	σ	1.03	0.98	0.00		
	V,%	154.92	117.98	0.00		
May	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
June	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
Year	$\overline{X}$	40.00	39.50	5.33	0.00	0.00
	σ	13.64	13.72	3.98		
	V,%	34.10	34.74	74.69		

Table 50

Average Temperature Above Freezing for Roof System 34, °F

Building Identification		34			34	
Roofing Layer		EPDM Elastomer	Urethane	Gypsum Plank	EPDM Elastomer	Fiberglass
Depth in Section (in.)		0.0	1.0	3.0	0.0	1.0
July	$\bar{X}$	96.95	85.37	73.29	95.78	83.46
	σ	2.56	1.37	0.15	2.13	1.02
	V,%	2.64	1.60	0.20	2.22	1.22
August	$\bar{X}$	93.90	83.72	73.20	93.53	82.31
	σ	3.22	1.74	0.19	2.47	1.18
	V,%	3.42	2.07	0.26	2.64	1.44
September	$\bar{X}$	83.76	78.46	72.71	84.52	78.15
	σ	3.02	1.70	0.23	2.46	1.23
	V,%	3.61	2.17	0.31	2.91	1.57
October	$\bar{X}$	74.05	73.32	72.14	75.13	73.70
	σ	1.32	0.75	0.10	1.75	0.87
	V,%	1.78	1.02	0.13	2.33	1.18
November	$\bar{X}$	61.35	64.83	71.13	62.57	66.93
	σ	1.86	1.49	0.19	1.77	1.12
	V,%	3.03	2.30	0.27	2.82	1.67
December	$\bar{X}$	57.23	60.62	70.64	58.63	64.13
	σ	1.98	1.58	0.20	2.57	1.87
	V,%	3.45	2.60	0.28	4.38	2.92
January	$\bar{X}$	55.79	57.07	70.23	56.53	61.37
	σ	2.82	1.14	0.15	1.90	2.10
	V,%	4.35	1.99	0.22	3.36	3.42
February	$\bar{X}$	59.43	59.53	70.52	59.46	62.60
	σ	4.11	1.89	0.22	3.02	1.33
	V,%	6.91	3.17	0.32	5.07	2.12
March	$\bar{X}$	64.76	64.05	71.04	64.77	66.91
	σ	3.55	1.74	0.23	2.04	1.41
	V,%	5.48	2.72	0.32	3.15	2.10
April	$\bar{X}$	70.75	70.48	71.69	73.38	72.09
	σ	1.31	1.12	0.17	1.69	1.09
	V,%	1.86	1.59	0.24	2.30	1.51
May	$\bar{X}$	81.14	76.36	72.25	83.22	77.13
	σ	1.69	0.94	0.11	2.31	1.11
	V,%	2.09	1.24	0.16	2.77	1.44
June	$\bar{X}$	90.00	81.39	72.79	92.28	81.68
	σ	1.46	0.77	0.10	2.02	0.99
	V,%	1.62	0.94	0.14	2.19	1.22
Year	$\bar{X}$	75.60	71.34	71.81	75.91	72.60
	σ	0.69	0.38	0.08	0.71	0.44
	V,%	0.91	0.54	0.11	0.94	0.60

°C = (°F - 32)/1.8

Table 51

Average Temperature Below Freezing for Roof System 34, ^{o}F

Building Identification		34			34	
Roofing Layer		EPDM Elastomer	Urethane	Gypsum Plank	E. Elastomer	Fiberglass
Depth in Section (in.)		0.0	1.0	3.0	0.0	1.0
July	$\overline{X}$ σ V,%	---	---	---	---	---
August	$\overline{X}$ σ V,%	---	---	---	---	---
September	$\overline{X}$ σ V,%	---	---	---	---	---
October	$\overline{X}$ σ V,%	---	---	---	---	---
November	$\overline{X}$ σ V,%	27.73 3.24 11.68	---	---	27.64 2.32 8.41	---
December	$\overline{X}$ σ V,%	27.10 1.16 4.28	---	---	28.09 1.82 6.48	---
January	$\overline{X}$ σ V,%	24.48 2.62 10.70	---	---	26.05 3.28 12.59	---
February	$\overline{X}$ σ V,%	24.70 1.98 8.03	---	---	26.69 1.50 5.63	---
March	$\overline{X}$ σ V,%	26.29 1.30 4.95	---	---	28.18 2.11 7.48	---
April	$\overline{X}$ σ V,%	28.94 0.00 0.00			30.47 0.00 0.00	
May	$\overline{X}$ σ V,%	---	---	---	---	---
June	$\overline{X}$ σ V,%	---	---	---	---	---
Year	$\overline{X}$ σ V,%	25.49 0.79 3.08	---	---	27.04 1.26 4.66	---

°C = (°F - 32)/1.8

Table 52

Average Cooling Rate for Roof System 34, °F/hr

Building Identification		34			34	
Roofing Layer		EPDM Elastomer	Urethane	Gypsum Plank	EPDM Elastomer	Fiberglass
Depth in Section (in.)		0.0	1.0	3.0	0.0	1.0
July	$\bar{X}$	2.06	1.13	0.19	2.11	1.15
	σ	0.17	0.09	0.02	0.19	0.10
	V,%	8.23	8.41	9.25	8.95	9.04
August	$\bar{X}$	2.21	1.20	0.19	2.32	1.27
	σ	0.25	0.14	0.02	0.21	0.12
	V,%	11.23	11.41	10.28	9.10	9.24
September	$\bar{X}$	2.46	1.31	0.12	2.52	1.33
	σ	0.19	0.10	0.01	0.18	0.09
	V,%	7.77	7.78	6.53	7.08	7.12
October	$\bar{X}$	2.38	1.23	0.09	2.21	1.14
	σ	0.18	0.09	0.01	0.25	0.13
	V,%	7.40	7.40	6.50	11.37	11.35
November	$\bar{X}$	2.32	1.20	0.09	2.09	1.09
	σ	0.18	0.09	0.01	0.16	0.08
	V,%	7.68	7.66	6.01	7.43	7.45
December	$\bar{X}$	2.17	1.12	0.09	1.82	0.95
	σ	0.16	0.08	0.01	0.20	0.10
	V,%	7.51	7.60	5.96	10.94	10.90
January	$\bar{X}$	2.18	1.12	0.09	1.86	0.97
	σ	0.16	0.08	0.01	0.16	0.09
	V,%	7.18	7.21	9.55	8.82	8.80
February	$\bar{X}$	2.45	1.27	0.10	2.27	1.18
	σ	0.30	0.16	0.01	0.25	0.13
	V,%	12.25	12.26	13.70	11.05	11.05
March	$\bar{X}$	2.70	1.41	0.12	2.65	1.38
	σ	0.21	0.11	0.01	0.25	0.13
	V,%	7.91	7.91	11.29	9.59	9.61
April	$\bar{X}$	2.55	1.38	0.18	2.64	1.43
	σ	0.16	0.09	0.02	0.18	0.09
	V,%	6.32	6.35	9.77	6.72	6.61
May	$\bar{X}$	2.33	1.27	0.21	2.37	1.30
	σ	0.10	0.06	0.01	0.20	0.11
	V,%	4.26	4.38	4.95	8.44	8.58
June	$\bar{X}$	2.12	1.16	0.20	2.20	1.21
	σ	0.14	0.08	0.01	0.12	0.07
	V,%	6.72	6.77	7.09	5.41	5.45
Year	$\bar{X}$	2.33	1.23	0.13	2.25	1.20
	σ	0.06	0.03	0.00	0.11	0.06
	V,%	2.65	2.65	2.69	5.02	5.00

°C/hr = (°F/hr)/1.8

Table 53

Average Warming Rate for Roof System 34, $^{o}F/hr$

Building Identification		34			34	
Roofing Layer		EPDM Elastomer	Urethane	Gypsum Plank	EPDM Elastomer	Fiberglass
Depth in Section (in.)		0.0	1.0	3.0	0.0	1.0
July	$\bar{X}$	5.10	2.96	0.17	4.22	2.31
	σ	0.46	0.27	0.02	0.35	0.20
	V,%	9.04	9.28	9.12	8.38	8.49
August	$\bar{X}$	5.51	3.07	0.15	4.62	2.52
	σ	0.69	0.39	0.02	0.41	0.23
	V,%	12.56	12.64	12.57	8.84	9.00
September	$\bar{X}$	5.35	2.43	0.17	4.99	2.63
	σ	0.46	0.19	0.02	0.36	0.19
	V,%	8.64	7.95	8.92	7.25	7.28
October	$\bar{X}$	2.76	1.58	0.16	4.39	2.27
	σ	0.21	0.12	0.02	0.46	0.24
	V,%	7.45	7.42	10.02	10.59	10.58
November	$\bar{X}$	2.69	1.54	0.15	4.12	2.14
	σ	0.22	0.12	0.01	0.33	0.17
	V,%	8.03	8.03	9.31	7.90	7.91
December	$\bar{X}$	2.49	1.42	0.13	3.63	1.90
	σ	0.16	0.09	0.01	0.37	0.19
	V,%	6.60	6.55	8.80	10.20	10.19
January	$\bar{X}$	2.46	1.41	0.13	3.72	1.94
	σ	0.18	0.11	0.01	0.34	0.18
	V,%	7.51	7.50	5.93	9.27	9.22
February	$\bar{X}$	2.90	1.66	0.16	4.58	2.37
	σ	0.42	0.24	0.02	0.53	0.27
	V,%	14.44	14.34	13.27	11.57	11.56
March	$\bar{X}$	4.42	2.11	0.19	5.31	2.75
	σ	0.41	0.19	0.01	0.53	0.28
	V,%	9.20	8.77	8.06	10.00	10.01
April	$\bar{X}$	6.36	3.31	0.17	5.33	2.89
	σ	0.43	0.19	0.01	0.28	0.15
	V,%	6.72	5.74	5.12	5.17	5.14
May	$\bar{X}$	5.81	3.33	0.19	4.78	2.61
	σ	0.29	0.17	0.01	0.45	0.25
	V,%	4.93	5.06	4.84	9.45	9.52
June	$\bar{X}$	5.26	3.06	0.19	4.46	2.44
	σ	0.39	0.23	0.01	0.25	0.14
	V,%	7.43	7.56	7.63	5.67	5.69
Year	$\bar{X}$	4.26	2.33	0.16	4.51	2.40
	σ	0.12	0.06	0.00	0.23	0.12
	V,%	2.74	2.70	2.62	5.03	5.00

°C/hr = (°F/hr)/1.8

Table 54

Average Length of Freezing Period for Roof System 34, Days

Building Identification		34			34	
Roofing Layer		EPDM Elastomer	Urethane	Gypsum Plank	EPDM Elastomer	Fiberglass
Depth in Section (in.)		0.0	1.0	3.0	0.0	1.0
July	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
August	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
September	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
October	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
November	$\overline{X}$	0.10			0.07	
	σ	0.07	---	---	0.02	---
	V,%	71.44			28.57	
December	$\overline{X}$	0.14			0.11	
	σ	0.03	---	---	0.05	---
	V,%	24.13			0.53	
January	$\overline{X}$	0.22			0.18	
	σ	0.07	---	---	0.10	---
	V,%	33.78			8.79	
February	$\overline{X}$	0.17			0.13	
	σ	0.04	---	---	0.08	---
	V,%	22.68			10.24	
March	$\overline{X}$	0.11			0.08	
	σ	0.03	---	---	0.03	---
	V,%	24.22			37.50	
April	$\overline{X}$	0.01			0.01	
	σ	0.03	---	---	0.00	---
	V,%	200.00			0.00	
May	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
June	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
Year	$\overline{X}$	0.17			0.13	
	σ	0.02	---	---	0.10	---
	V,%	10.64			72.66	

Table 55

Average Length of Thawing Period for Roof System 34, Days

Building Identification		34			34	
Roofing Layer		EPDM Elastomer	Urethane	Gypsum Plank	EPDM Elastomer	Fiberglass
Depth in Section (in.)		0.0	1.0	3.0	0.0	1.0
July	$\bar{X}$ / σ / V,%	---	---	---	---	---
August	$\bar{X}$ / σ / V,%	---	---	---	---	---
September	$\bar{X}$ / σ / V,%	---	---	---	---	---
October	$\bar{X}$ / σ / V,%	---	---	---	---	---
November	$\bar{X}$	6.49	---	---	16.37	---
	σ	2.46			5.87	
	V,%	37.85			66.38	
December	$\bar{X}$	2.61	---	---	7.24	---
	σ	1.15			4.74	
	V,%	44.12			77.56	
January	$\bar{X}$	1.26	---	---	2.85	---
	σ	0.25			2.92	
	V,%	19.85			102.48	
February	$\bar{X}$	1.68	---	---	2.57	---
	σ	0.53			2.81	
	V,%	31.28			105.26	
March	$\bar{X}$	2.75	---	---	6.84	---
	σ	1.12			6.33	
	V,%	40.69			99.17	
April	$\bar{X}$	24.99	---	---	24.16	---
	σ	10.02			5.00	
	V,%	40.09			38.84	
May	$\bar{X}$ / σ / V,%	---	---	---	---	---
June	$\bar{X}$ / σ / V,%	---	---	---	---	---
Year	$\bar{X}$	5.56	---	---	10.96	---
	σ	0.25			29.69	
	V,%	4.51			289.41	

Table 56

Average Number of Freeze-Thaw Cycles for Roof System

Building Identification		34			34	
Roofing Layer		EPDM Elastomer	Urethane	Gypsum Plank	EPDM Elastomer	Fiberglass
Depth in Section (in.)		0.0	1.0	3.0	0.0	1.0
July	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
August	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
September	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
October	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
November	$\overline{X}$	4.00	0.00	0.00	1.67	0.00
	σ	1.63			1.63	
	V,%	40.82			97.96	
December	$\overline{X}$	11.50	0.00	0.00	5.50	0.00
	σ	3.79			4.51	
	V,%	32.92			81.92	
January	$\overline{X}$	20.50	0.00	0.00	12.67	0.00
	σ	3.42			5.47	
	V,%	16.66			43.15	
February	$\overline{X}$	15.25	0.00	0.00	10.83	0.00
	σ	5.32			5.04	
	V,%	34.85			46.49	
March	$\overline{X}$	11.00	0.00	0.00	5.17	0.00
	σ	3.92			3.76	
	V,%	35.60			72.85	
April	$\overline{X}$	0.50	0.00	0.00	0.50	0.00
	σ	1.00			0.84	
	V,%	200.00			167.33	
May	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
June	$\overline{X}$					
	σ	---	---	---	---	---
	V,%					
Year	$\overline{X}$	62.75	0.00	0.00	36.33	0.00
	σ	2.99			12.29	
	V,%	4.76			33.83	

Table 57

Transient Heat Flux, Btu/hr-sq ft

Building Identification		5	18	2	3	3
Roofing Layer		Figure 1 5	Figure 2 18	Figure 3 2	Figure 4 3A	Figure 5 3B
Depth in Section (in.)		Total	Total	Total	Total	Total
July	$\overline{X}$	4.61	2.80	30.44	25.17	16.58
	σ	0.77	1.41	2.74	2.55	1.54
	V,%	16.64	50.33	9.01	10.13	9.30
August	$\overline{X}$	3.88	1.44	26.95	22.12	14.10
	σ	1.01	1.94	3.12	2.79	1.56
	V,%	25.96	134.46	11.56	12.62	11.06
September	$\overline{X}$	0.99	-6.22	12.49	11.05	5.74
	σ	1.00	2.54	3.06	2.65	1.24
	V,%	101.14	40.78	24.48	24.00	21.58
October	$\overline{X}$	-2.01	-14.92	-0.68	1.30	-0.45
	σ	0.44	2.16	2.52	1.72	1.04
	V,%	22.10	14.44	367.30	132.53	229.10
November	$\overline{X}$	-6.94	-28.85	-18.13	-12.66	-7.37
	σ	0.88	2.49	2.89	2.24	1.14
	V,%	12.66	8.64	15.93	17.69	15.47
December	$\overline{X}$	-9.37	-34.32	-25.47	-18.49	-10.26
	σ	0.93	4.28	5.33	3.92	2.15
	V,%	9.94	12.48	20.94	21.17	20.91
January	$\overline{X}$	-11.46	-40.72	-32.96	-23.73	-13.18
	σ	0.66	5.03	6.16	4.86	2.49
	V,%	5.78	12.35	18.68	20.46	18.91
February	$\overline{X}$	-10.09	-39.34	-30.59	-21.28	-12.32
	σ	1.09	3.02	3.61	3.01	1.47
	V,%	10.79	7.67	11.81	14.16	11.97
March	$\overline{X}$	-7.51	-31.02	-19.28	-13.41	-7.59
	σ	1.01	3.22	3.82	2.59	1.52
	V,%	13.52	10.39	19.80	19.31	20.01
April	$\overline{X}$	-3.83	-20.84	-1.27	0.47	2.14
	σ	0.67	2.34	2.89	1.99	1.16
	V,%	17.47	11.23	226.94	422.79	54.08
May	$\overline{X}$	-0.64	-11.28	13.43	11.99	9.76
	σ	0.55	1.65	3.02	2.63	1.65
	V,%	85.37	14.63	22.48	21.93	16.87
June	$\overline{X}$	2.22	-2.08	25.34	21.14	15.07
	σ	0.41	1.89	2.60	2.14	1.25
	V,%	18.58	90.93	10.27	10.12	8.28
Year	$\overline{X}$	-3.31	-18.66	-1.47	0.43	1.09
	σ	0.22	1.11	1.20	0.72	0.48
	V,%	6.58	5.95	81.19	167.08	43.50

1 Btu/hr - sq ft = 3.15 W/m2

Table 57 (Cont'd)

Building Identification		4	4	34	34
Roofing Layer		Figure 6 4A	Figure 7 4B	Figure 8 34A	Figure 9 34B
Depth in Section (in.)		Total	Total	Total	Total
July	$\bar{X}$	18.67	11.38	6.74	9.13
	σ	1.70	1.05	0.69	0.81
	V,%	9.09	9.22	10.23	8.92
August	$\bar{X}$	17.27	10.36	6.00	8.27
	σ	2.06	1.22	0.89	0.95
	V,%	11.91	11.80	14.89	11.46
September	$\bar{X}$	10.01	5.48	3.33	4.81
	σ	2.13	1.19	0.88	0.94
	V,%	21.30	21.73	26.34	19.65
October	$\bar{X}$	2.24	0.85	0.62	1.20
	σ	1.57	0.90	0.39	0.67
	V,%	70.15	105.75	61.96	55.86
November	$\bar{X}$	-9.31	-5.63	-3.75	-3.99
	σ	1.95	1.09	0.77	0.85
	V,%	20.96	19.43	20.46	21.39
December	$\bar{X}$	-14.00	-8.24	-5.92	-6.14
	σ	3.29	1.87	0.81	1.44
	V,%	23.50	22.71	13.70	23.47
January	$\bar{X}$	-18.83	-10.98	-7.75	-8.26
	σ	3.72	2.14	0.58	1.62
	V,%	19.73	19.53	7.56	19.69
February	$\bar{X}$	-16.93	-9.95	-6.48	-7.33
	σ	2.33	1.34	0.97	1.02
	V,%	13.77	13.42	14.91	13.99
March	$\bar{X}$	-9.54	-5.76	-4.14	-3.96
	σ	2.45	1.38	0.90	1.08
	V,%	25.67	23.99	21.62	27.20
April	$\bar{X}$	-0.05	0.37	-0.78	0.40
	σ	1.86	1.05	0.58	0.83
	V,%	3558.60	284.21	74.13	209.76
May	$\bar{X}$	8.32	5.55	2.12	4.31
	σ	1.82	1.11	0.48	0.88
	V,%	21.89	19.95	22.86	20.53
June	$\bar{X}$	15.99	9.97	4.66	7.79
	σ	1.67	0.98	0.38	0.77
	V,%	10.48	9.82	8.16	9.95
Year	$\bar{X}$	0.42	0.34	-0.41	0.56
	σ	0.74	0.42	0.19	0.33
	V,%	175.28	123.69	46.50	58.12

1 Btu/hr - sq ft = 3.15 W/m^2

Table 58

Thermal Stains in Composite Roof Systems for Cape Hatteras, NC

Roof System	Roofing Layer	Depth in Section (in)	Temperature $\overline{X}$(F)	Temperature σ(F)	Temperature V(%)	Coefficient of Thermal Expansion (in/in/F)	Thermal Strain (in/in) *
5	25 mil Diathon	0.0	71.52	26.47	37.02	4×10^{-5}	6.35×10^{-3}
	Polyurethane Foam	1.0	78.14	4.01	5.13	6×10^{-5}	1.44×10^{-3}
	Gypsum Concrete	3.0	78.51	2.96	3.77	8.5×10^{-6}	1.51×10^{-4}
	Gypsum Plank	4.0	79.22	1.49	1.88	8.5×10^{-6}	7.60×10^{-5}
18	Gacoflex	0.0	67.97	20.82	30.65	7×10^{-5}	8.74×10^{-3}
	Built-up Roofing	0.5	68.97	19.66	28.53	15×10^{-6}	1.77×10^{-3}
	Insulation	1.0	74.45	12.81	17.22	6×10^{-5}	4.61×10^{-3}
	Gypsum Plank	2.5	82.44	2.95	3.58	8.5×10^{-6}	1.50×10^{-4}
2	No. 5 Gravel	0.0	71.39	26.09	36.55	--	--
	Styrofoam Insulation	2.0	70.79	15.80	22.32	6×10^{-5}	5.69×10^{-3}
	Built-up Roofing	3.0	70.37	5.63	8.00	15×10^{-6}	5.07×10^{-4}
	Gypsum Concrete	4.5	70.55	3.56	5.05	8.5×10^{-6}	1.80×10^{-4}
	Gypsum Plank	6.5	71.37	1.26	1.77	8.5×10^{-6}	6.43×10^{-5}

* Thermal Strain at $(\overline{X} \pm 3\sigma)^{\circ}F$

°C = (°F - 32)/1.8

Table 58 (Cont'd)

Roof System	Roofing Layer	Depth in Section (in)	Temperature			Coefficient of Thermal Expansion (in/in/F)	Thermal Strain (in/in) *
			$\overline{X}$(F)	σ(F)	V(%)		
3A	Light Colored Gravel	0.0	71.26	26.06	36.52	--	--
		0.5	71.22	26.00	36.52	--	--
	Built-up Roofing	1.0	71.09	24.88	35.00	15×10^{-6}	2.24×10^{-3}
	Urethane Bound	1.5	71.31	15.30	21.45	6×10^{-5}	5.51×10^{-3}
	Gypsum Plank	3.0	71.73	2.78	3.88	8.5×10^{-6}	1.42×10^{-4}
3B	Light Colored Gravel	0.00	71.40	26.52	37.15	--	--
		0.05	71.35	26.58	37.27	--	--
	Built-up Roofing	1.0	71.15	26.50	37.26	15×10^{-6}	2.38×10^{-3}
	Urethane Board	4.5	71.15	8.55	12.02	6×10^{-5}	3.08×10^{-3}
	Gypsum Plank	7.0	71.83	0.62	0.87	8.5×10^{-6}	3.16×10^{-5}

* Thermal Strain at $(\overline{X} \pm 3\sigma)^{\circ}F$

°C = (°F - 32)/1.8

Table 58 (Cont'd)

Roof System	Roofing Layer	Depth in Section (in)	Temperature			Coefficient of Thermal Expansion (in/in/F)	Thermal Strain (in/in) *
			$\overline{X}$(F)	σ(F)	V(%)		
4A	GAF Mineral Shield	0.0	72.53	24.72	34.10	7.5×10^{-5}	1.11×10^{-2}
		0.5	72.28	23.82	32.97	7.5×10^{-5}	1.07×10^{-2}
	Urethane Board	1.0	72.05	14.73	20.45	6×10^{-5}	5.30×10^{-3}
	Gypsum Plank	2.5	71.89	2.75	3.83	8.5×10^{-6}	1.40×10^{-4}
4B	GAF Mineral Shield	0.0	72.50	25.38	35.03	7.5×10^{-5}	1.14×10^{-2}
		0.5	72.24	25.50	35.32	7.5×10^{-5}	1.14×10^{-2}
	Urethane Board	1.5	71.80	20.86	29.06	6×10^{-5}	7.50×10^{-3}
		4.0	71.60	8.51	11.89	6×10^{-5}	3.06×10^{-3}
	Gypsum Plank	6.5	71.89	0.63	0.88	8.5×10^{-6}	3.21×10^{-5}
34A	EPDM Elastomer	0.0	71.29	27.08	37.99	7.2×10^{-5}	1.17×10^{-2}
	Urethane	1.0	71.18	15.27	21.45	6×10^{-5}	5.50×10^{-3}
	Gypsum Plank	3.0	71.81	1.88	2.62	8.5×10^{-6}	9.59×10^{-5}
34B	EPDM Elastomer	0.0	73.47	25.35	34.52	7.2×10^{-5}	1.10×10^{-2}
	Fiberglass	1.0	72.60	12.97	17.87	6×10^{-5}	4.67×10^{-3}

* Thermal Strain at $(\overline{X} \pm 3\sigma)$F

°C = (°F - 32)/1.8

Table 59

Roof System Ranking in Relation to Computed Parameters

Performance Ranking	Freeze-Thaw Cycles	Cooling Rate	Length of Freezing Period	Thermal Strain	Heat Flux
High Performance					
1	2	18	2	3B	34A
2	4A	5	4A	3A	34B
3	3A	4A	3A	2	5
4	4B	34A	4B	5	4B
5	3B	3A	3B	18	3B
6	5	2	5	4A	4A
7	18	4B	18	4B	3A
8	34A	3B	34A	34A	2
9	34B	34B	34B	34B	18
Low Performance					

Building Number	Roof System
5	5
18	18
2	2
3	3A,3B
4	4A,4B
34	34A,34B

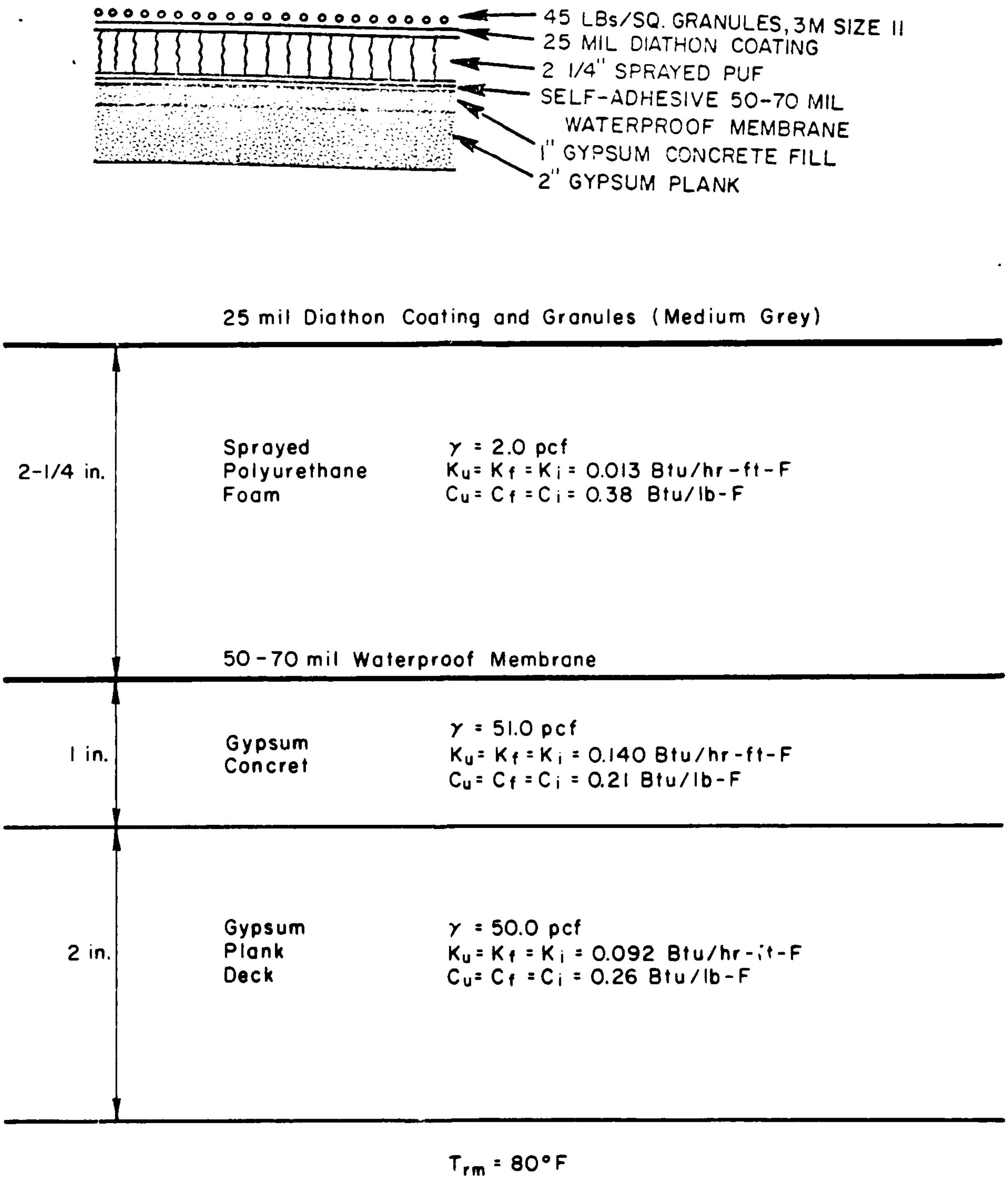
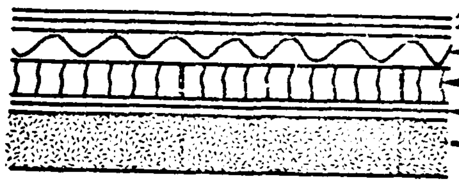


Figure 1. Roof System 5, Building 5, Cape Hatteras, NC.

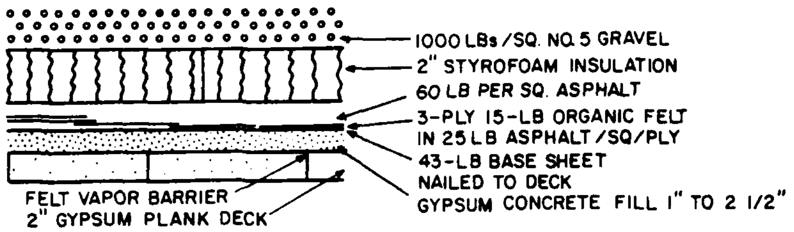


4 mil Gacoflex UA-65 Over 40 mil Gacoflex U-6321

1/2 in.	Existing Built-Up Roof	γ = 70.0 pcf $C_u = C_f = C_i$ = 0.35 Btu/lb-F $K_u = K_f = K_i$ = 0.094 Btu/hr-ft-F
1 in.	Insulation	γ = 2.0 pcf $K_u = K_f = K_i$ = 0.020 Btu/hr-ft-F $C_u = C_f = C_i$ = 0.29 Btu/lb-F Vapor Barrier
2 in.	Gypsum Plank Deck	γ = 50.0 pcf $K_u = K_f = K_i$ = 0.092 Btu/hr-ft-F $C_u = C_f = C_i$ = 0.26 Btu/lb-F

T_{rm} = 85°F

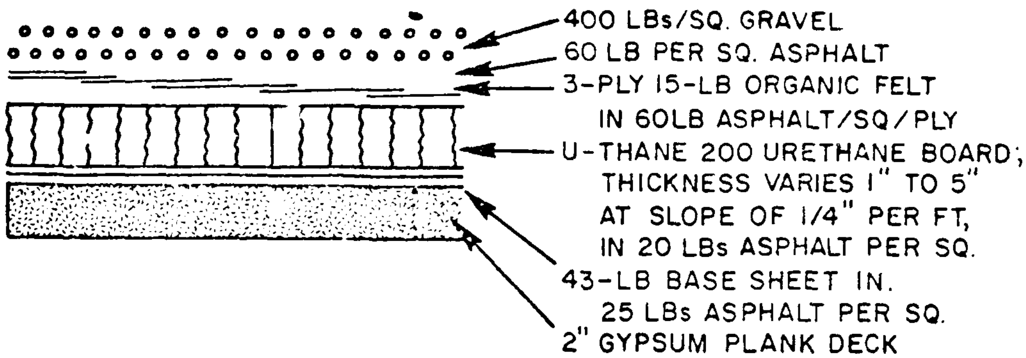
Figure 2. Roof System 18, Building 18, Cape Hatteras, NC.



1 in.	1000 lbs/sq. No. 5 Gravel Light Colored	γ = 135.0 pcf K_u = 1.21 Btu/hr-ft-F K_f = 1.09 Btu/hr-ft-F K_i = 0.98 Btu/hr-ft-F	C_u = 0.23 Btu/lb-F C_f = 2.77 Btu/lb-F C_i = 0.21 Btu/lb-F w = 4%
2 in.	Styrofoam Insulation	γ = 2.0 pcf $K_u = K_f = K_i$ = 0.020 Btu/hr-ft-F $C_u = C_f = C_i$ = 0.29 Btu/lb-F	
1/2 in.	3 Ply Built-Up Roofing	γ = 70.0 pcf $K_u = K_f = K_i$ = 0.094 Btu/hr-ft-F	$C_u = C_f = C_i$ = 0.35 Btu/lb-F
2 in.	Gypsum Concrete	γ = 51.0 pcf $K_u = K_f = K_i$ = 0.140 Btu/hr-ft-F $C_u = C_f = C_i$ = 0.21 Btu/lb-F Vapor Barrier	
2 in.	Gypsum Plank	γ = 50.0 pcf $K_u = K_f = K_i$ = 0.092 Btu/hr-ft-F $C_u = C_f = C_i$ = 0.26 Btu/lb-F	

T_{rm} = 72°F

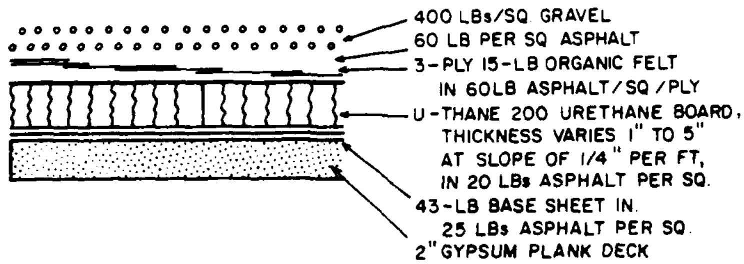
Figure 3. Roof system 2, Building 2, Cape Hatteras, NC.



1/2 in.	400 lb/sq Gravel Light Colored	γ = 135.0 pcf K_u = 1.21 Btu/hr-ft-F K_f = 1.09 Btu/hr-ft-F	K_i = 0.98 Btu/ft-F C_u = 0.23 Btu/lb-F C_f = 2.77 Btu/lb-F	C_i = 0.21 Btu/lb-F w = 4 %
1/2 in.	3 Ply Built-Up Roofing	γ = 70.0 pcf $K_u = K_f = K_i$ = 0.094 Btu/hr-ft-F	$C_u = C_f = C_i$ = 0.35 Btu/lb-F	
1 in.	U-Thane 200 Urethane Board	γ = 2.0 pcf $K_u = K_f = K_i$ = 0.014 Btu/hr-ft-F $C_u = C_f = C_i$ = 0.38 Btu/lb-F		
1/6 in.	Asphalt and Base Sheet			
2 in.	Gypsum Plank Deck	γ = 50.0 pcf $K_u = K_f = K_i$ = 0.092 Btu/hr-ft-F $C_u = C_f = C_i$ = 0.26 Btu/hr-ft-F		

T_{rm} = 72°F

Figure 4. Roof System 3A, Building 3, Cape Hatteras, NC.



Thickness	Layer	Properties		
1/2 in.	400 lb/sq Gravel Light Colored	γ = 135.0 pcf K_u = 1.21 Btu/hr-ft-F K_f = 1.09 Btu/hr-ft-F	K_t = 0.98 Btu/ft-F C_u = 0.23 Btu/lb-F C_f = 2.77 Btu/lb-F	C_t = 0.21 Btu/lb-F w = 4 %
1/2 in.	3 Ply Built-Up Roofing	γ = 70.0 pcf $K_u = K_f = K_t$ = 0.094 Btu/hr-ft-F	$C_u = C_f = C_t$ = 0.35 Btu/lb-F	
5 in.	U-Thane 200 Urethane Board	γ = 2.0 pcf $K_u = K_f = K_t$ = 0.014 Btu/hr-ft-F $C_u = C_f = C_t$ = 0.38 Btu/lb-F		
1/6 in.	Asphalt and Base Sheet			
2 in.	Gypsum Plank Deck	γ = 50.0 pcf $K_u = K_f = K_t$ = 0.092 Btu/hr-ft-F $C_u = C_f = C_t$ = 0.26 Btu/hr-ft-F		

T_{rm} = 72°F

Figure 5. Roof System 3B, Building 3, Cape Hatteras, NC.

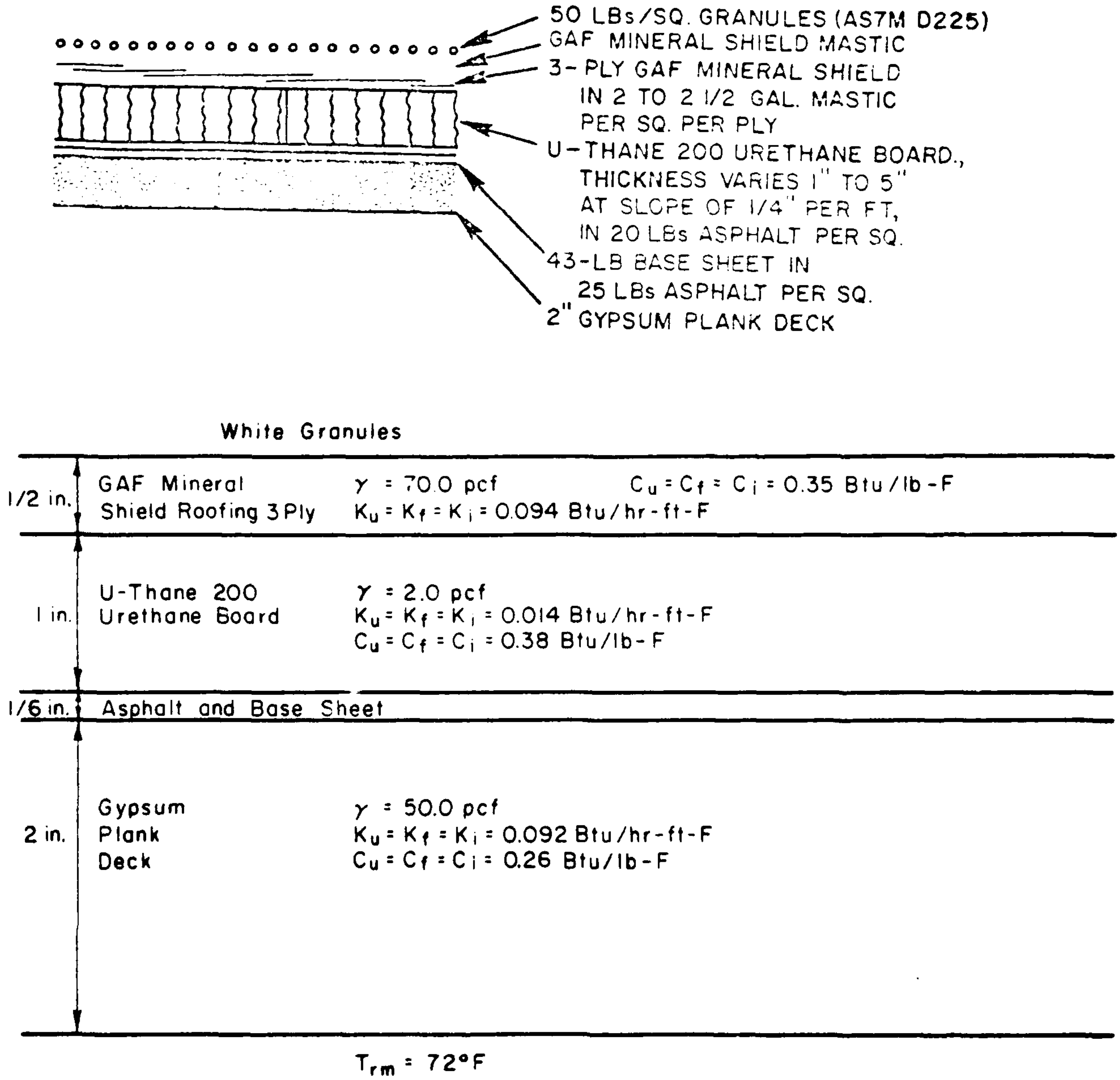


Figure 6. Roof System 4A, Building 4, Ca.e Hatteras, NC.

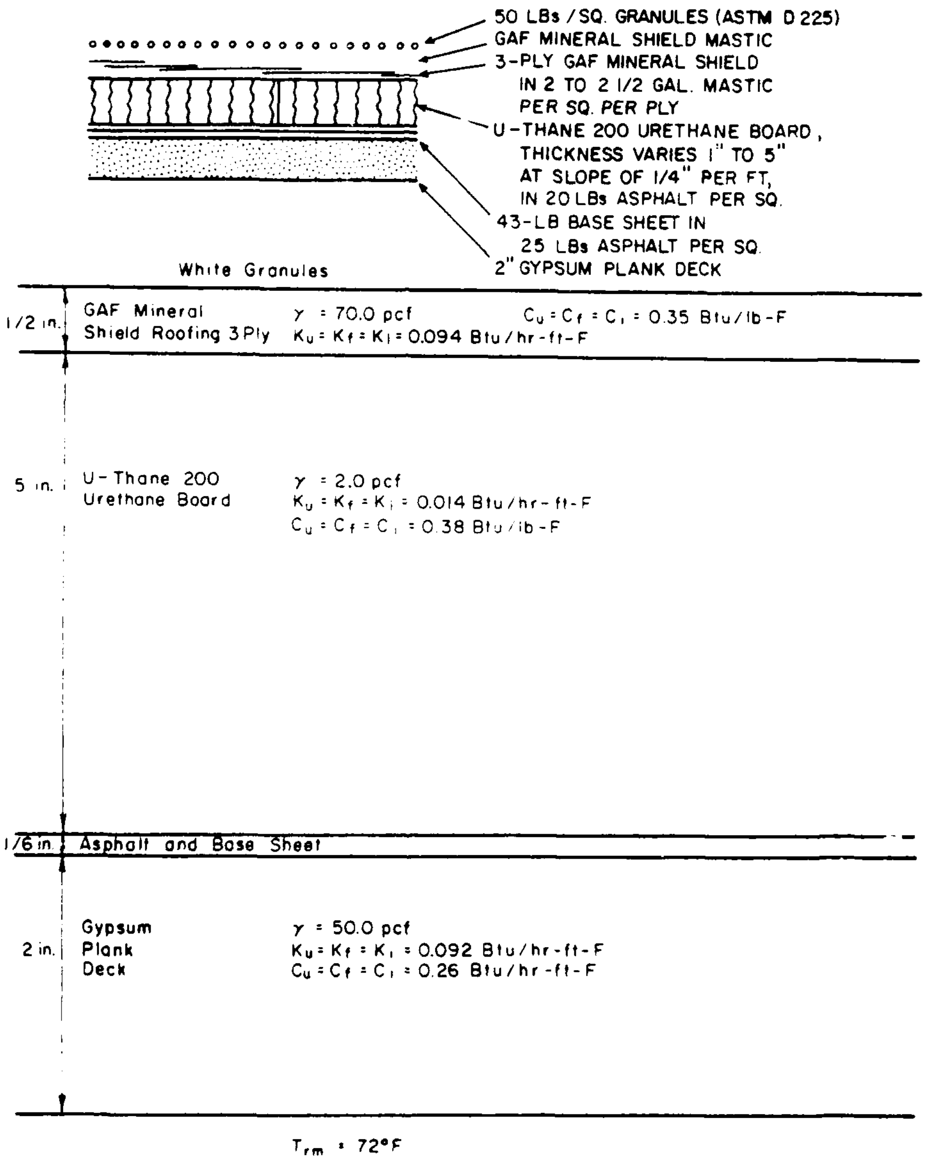


Figure 7. Roof System 4B, Building 4, Cape Hatteras, NC.

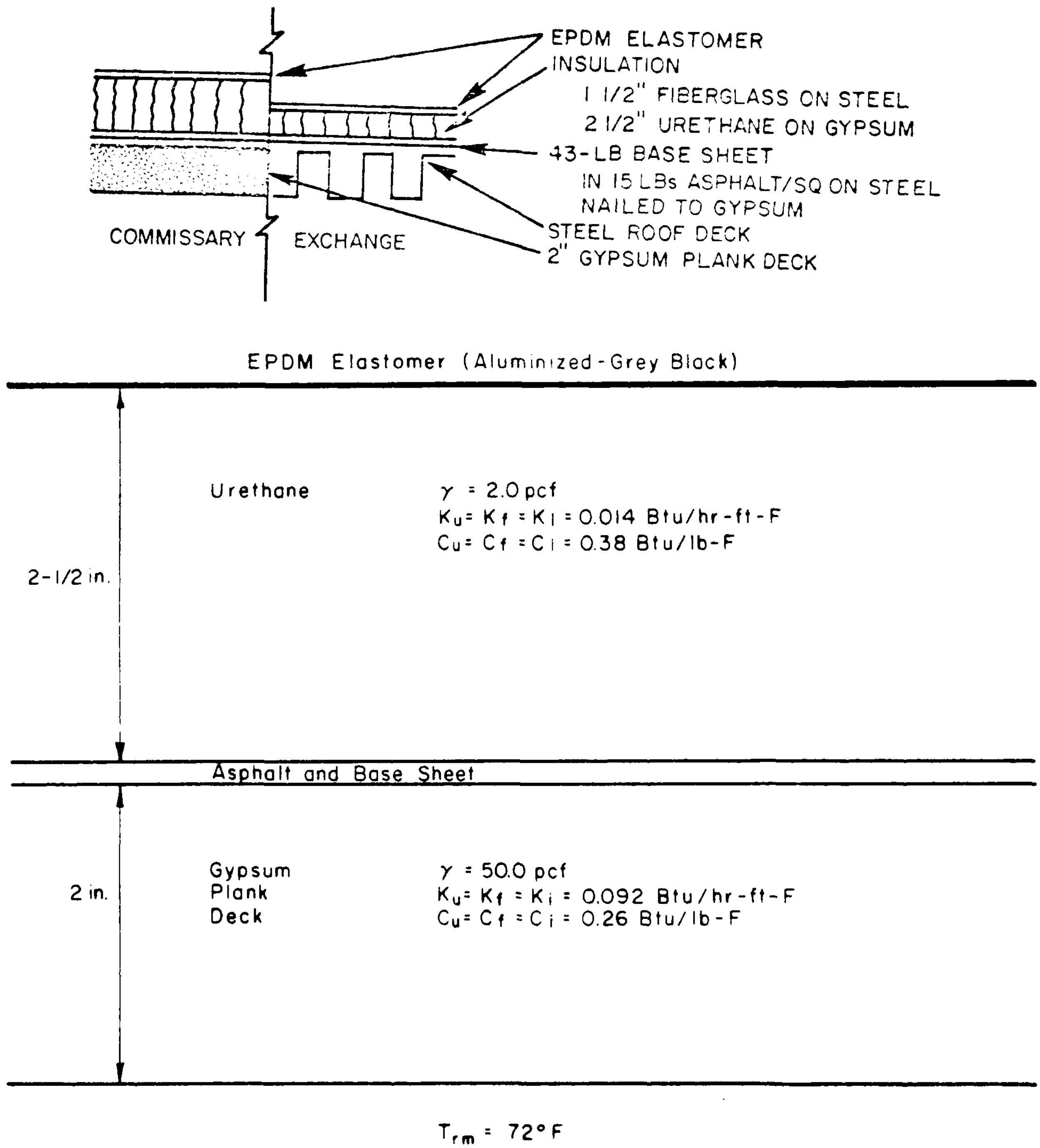


Figure 8. Roof System 34A, Building 34, Cape Hatteras, NC.

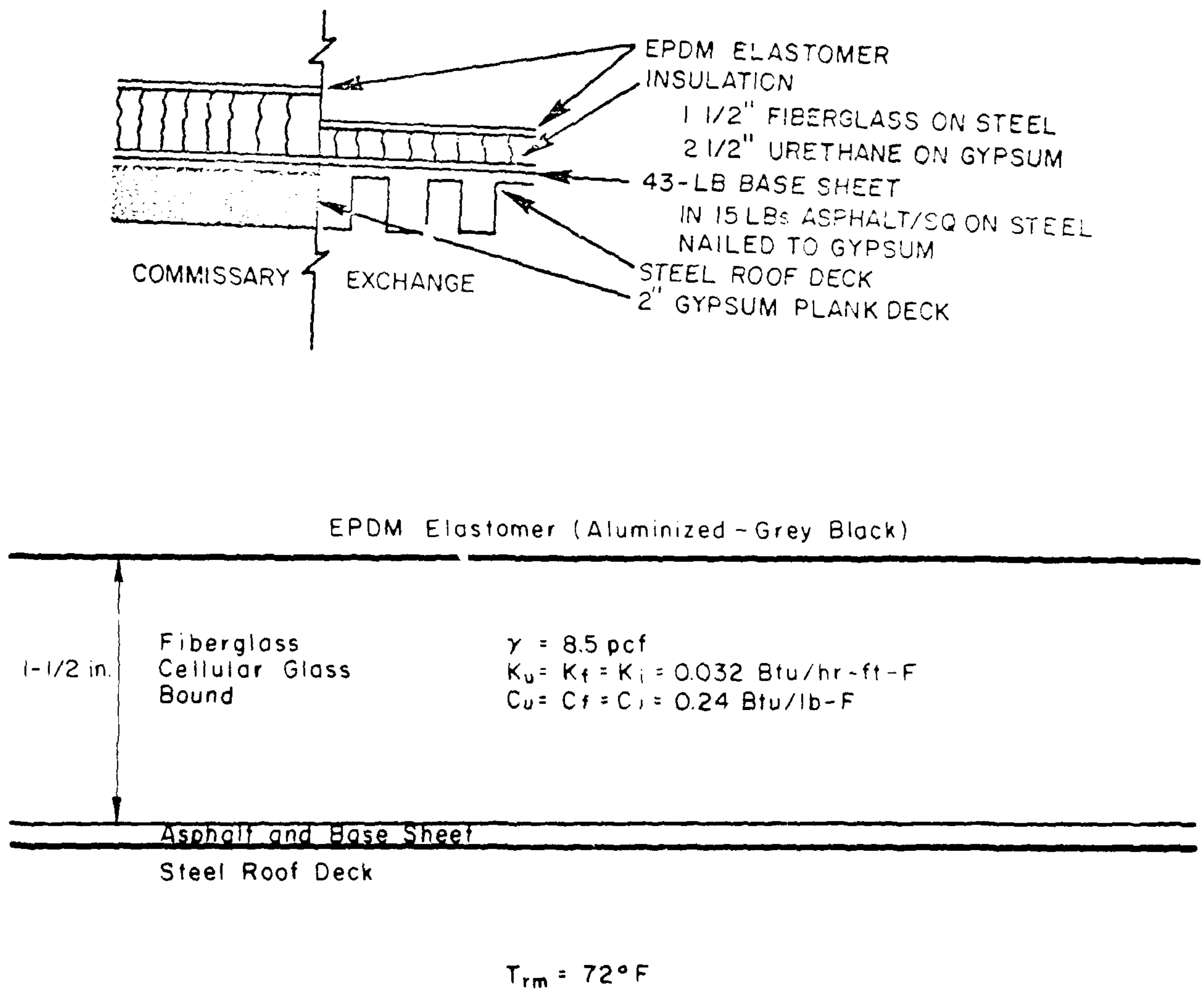


Figure 9. Roof System 34B, Building 34, Cape Hatteras, NC.

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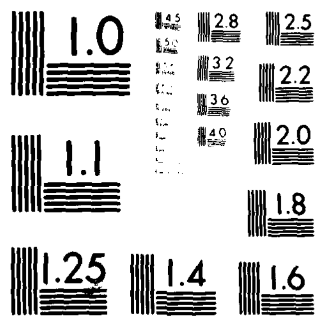

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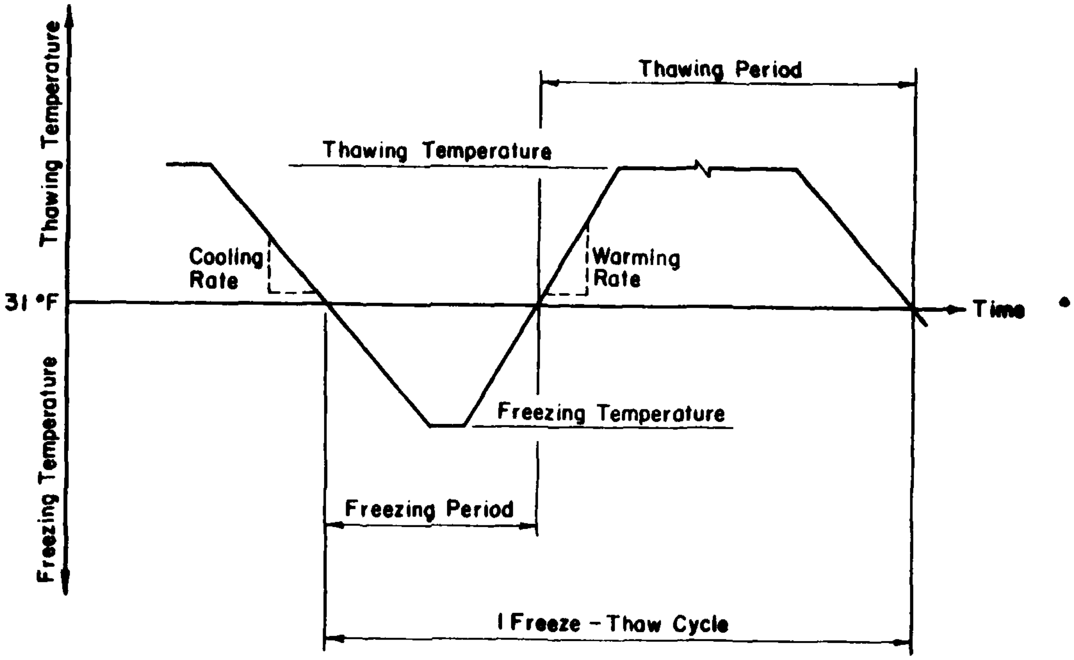

Figure 10. Idealized freeze-thaw cycle for a roof system.

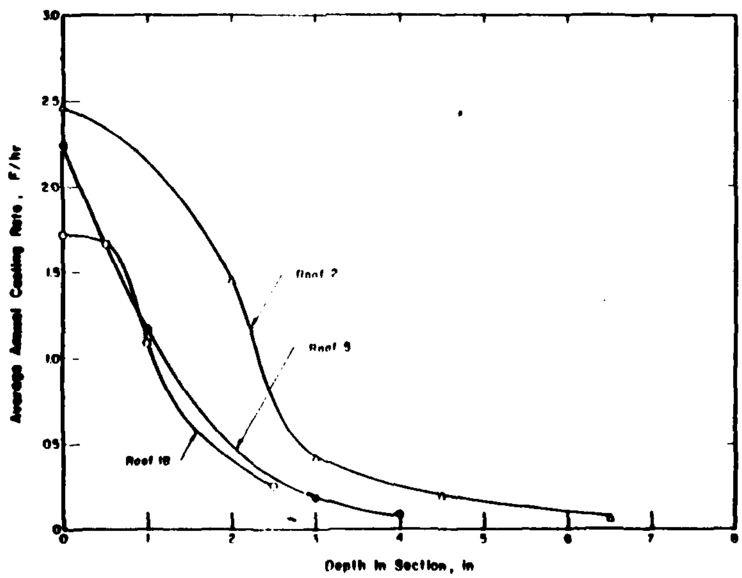

Figure 11. Average cooling rates for roof systems on Buildings 5, 18, and 2.

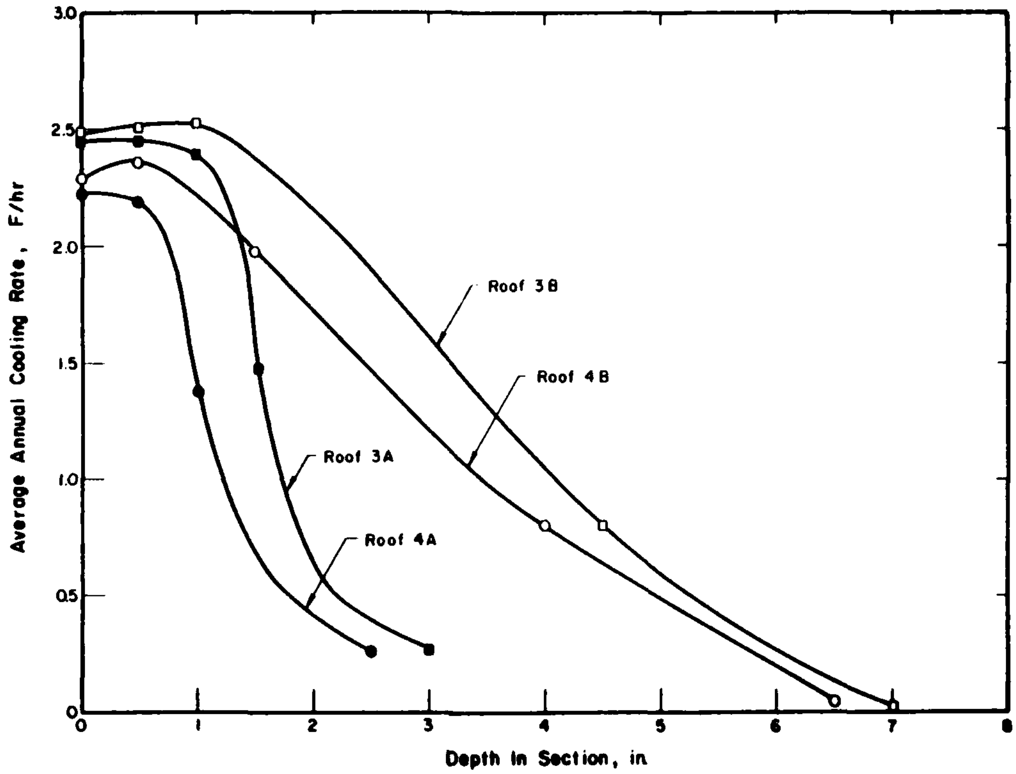

Figure 12. Average cooling rates for roof systems on Buildings 3 and 4.

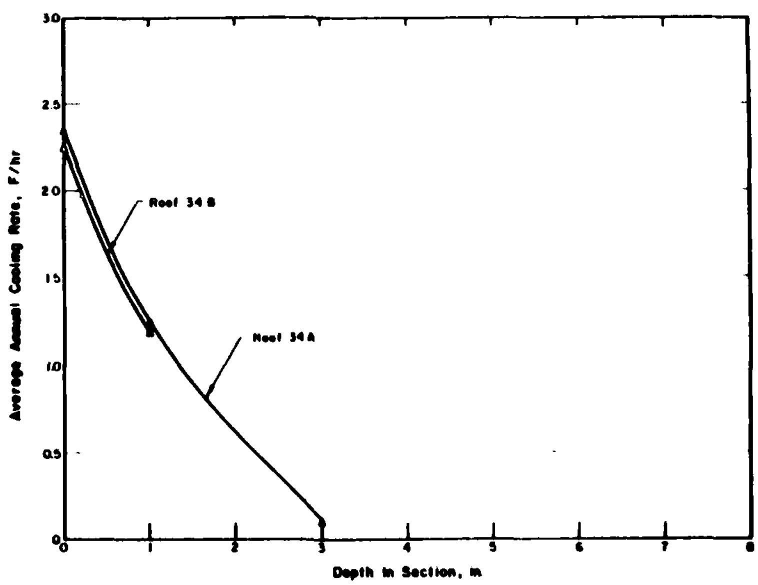

Figure 13. Average cooling rates for roof systems on Building 34.

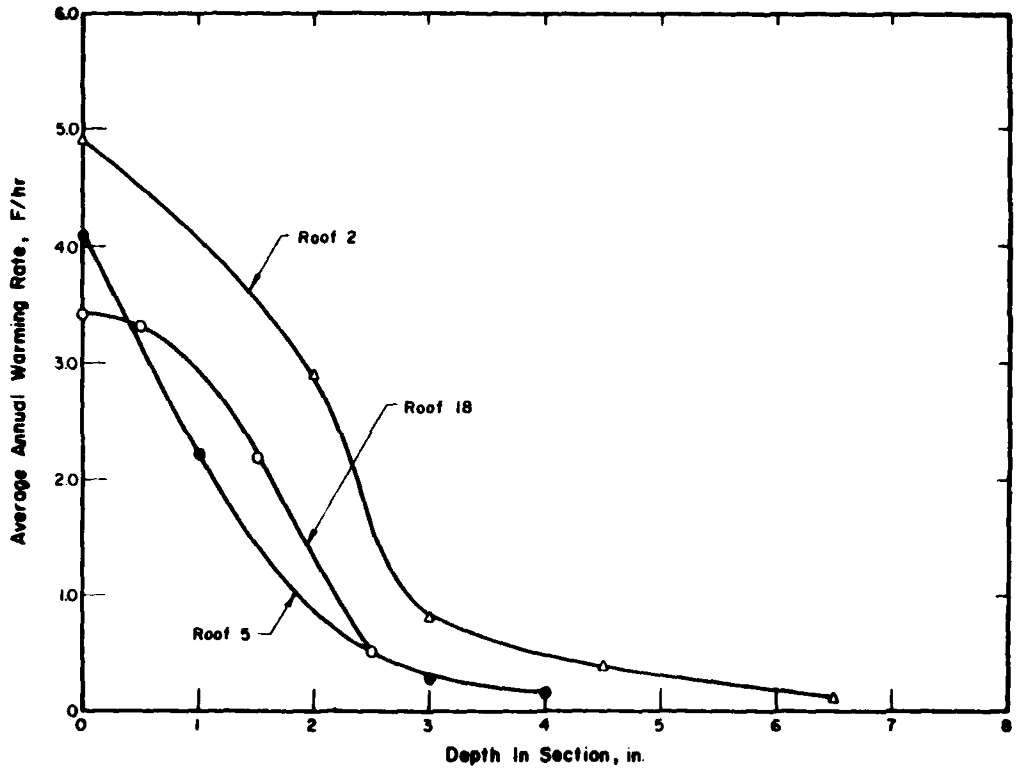

Figure 14. Average warming rates for roof systems on Buildings 5, 18, and 2.

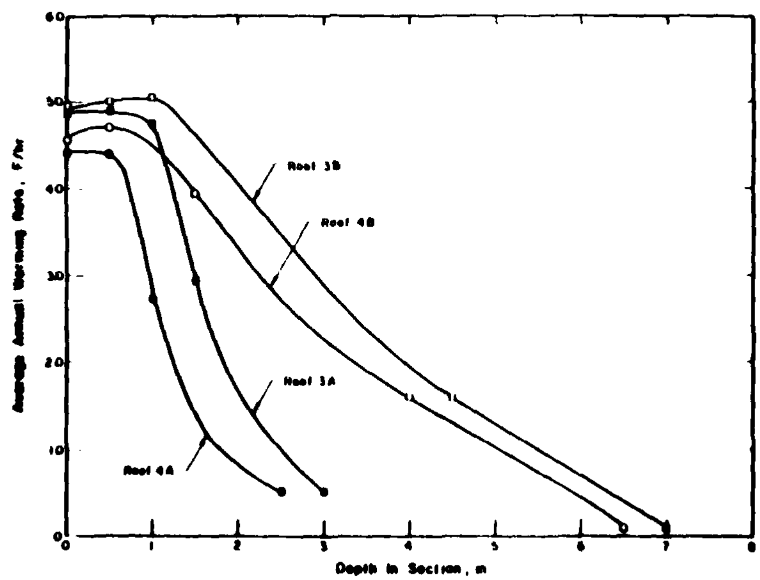

Figure 15. Average warming rates for roof systems on Buildings 3 and 4.

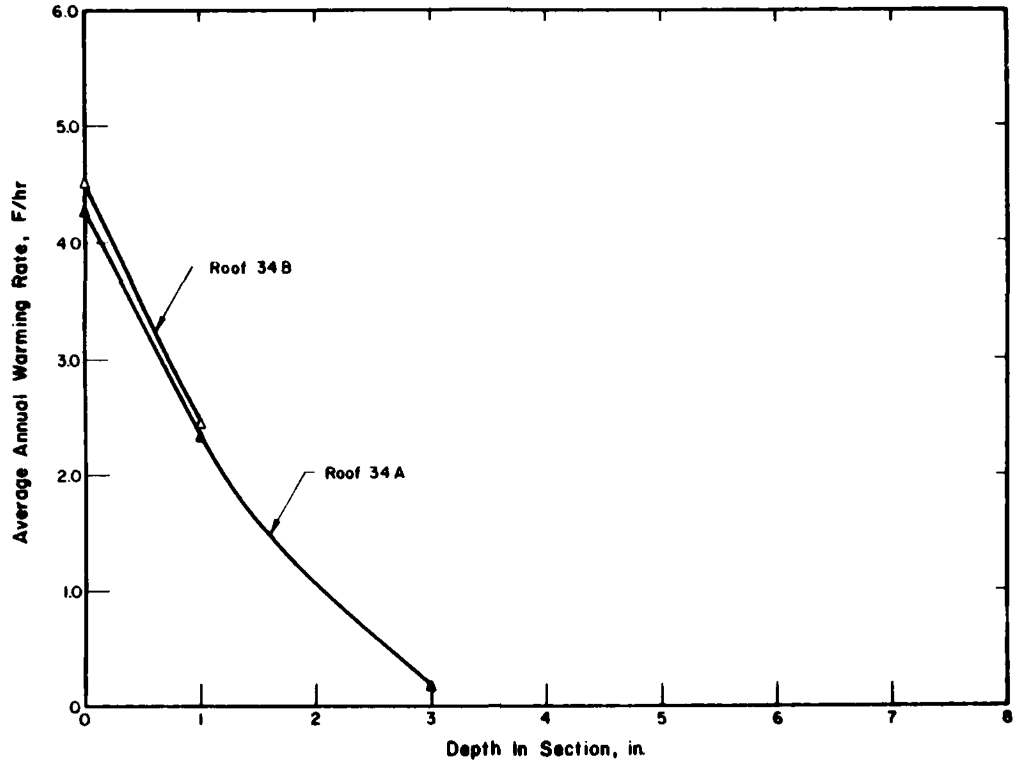

Figure 16. Average warming rates for roof systems on Building 34.

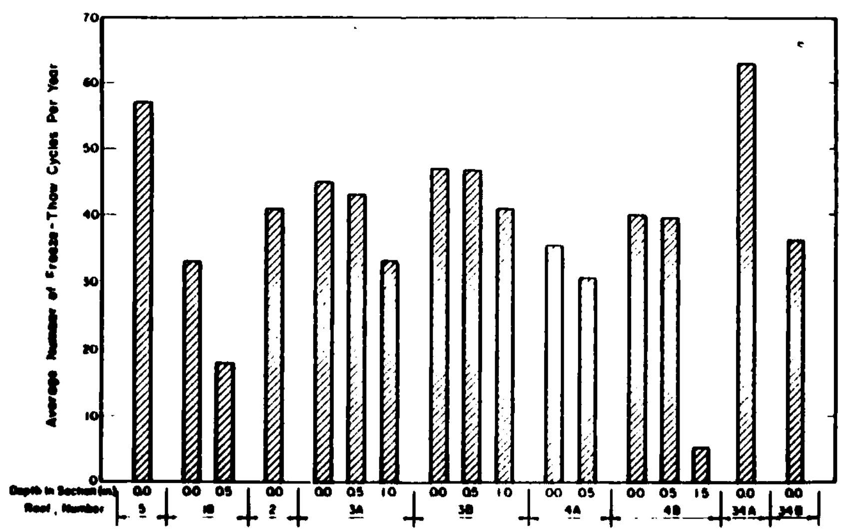

Figure 17. Average number of freeze-thaw cycles per year.

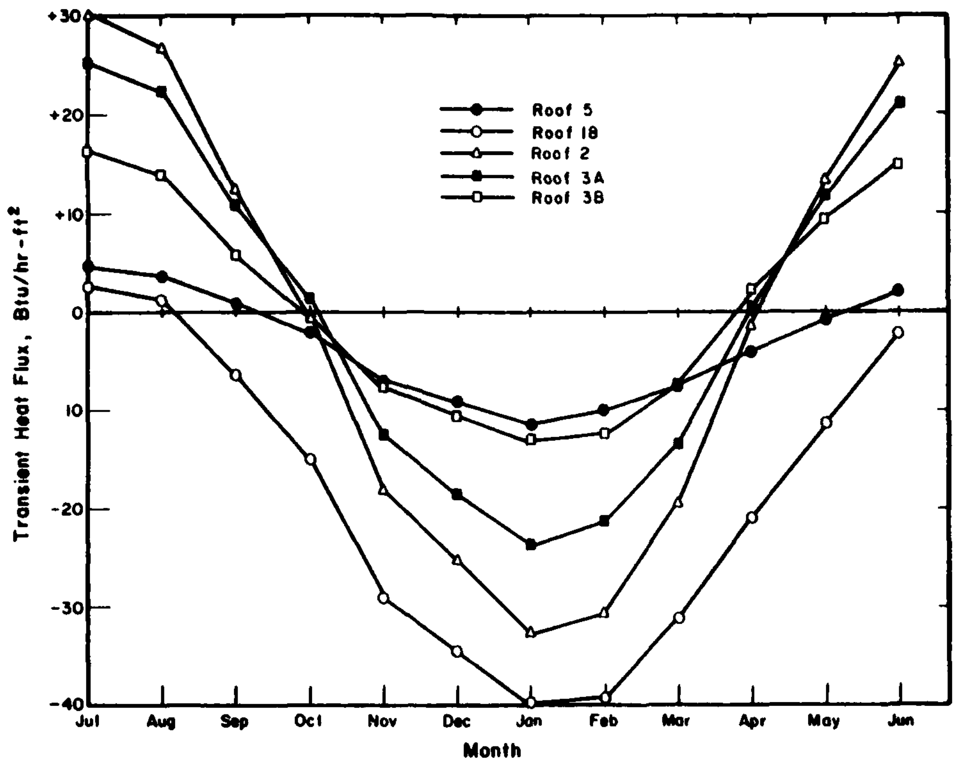

Figure 18. Transient heat flux for Building 5, 18, 2, and 3.

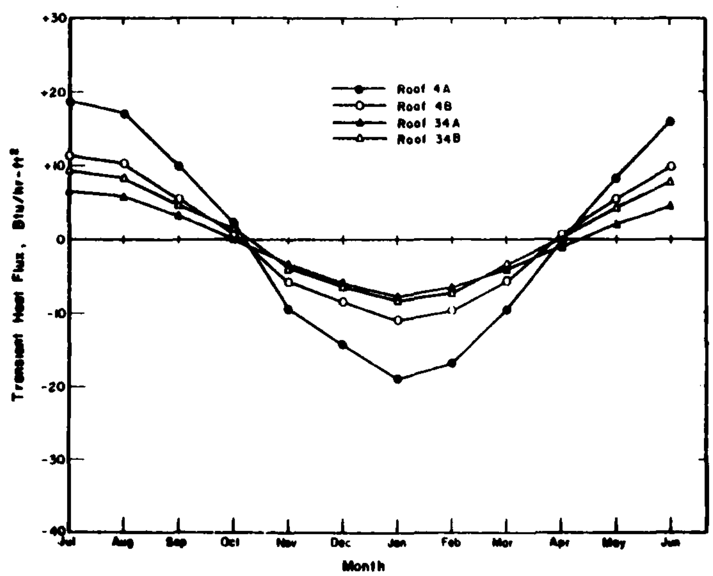

Figure 19. Transient heat flux for Buildings 4 and 34.

List of Abbreviations

BUR	Built-up roofing		
C_f	Mass heat capacity of freezing material		Btu/lb^{o}F
C_i	Mass heat capacity of a frozen material		Btu/lb-^{o}F
C_u	Mass heat capacity of an unfrozen material		Btu/lb-$_{u_F}$
EPDM	Ethylene Propylene Diene Monomer		
k	General thermal conductivity designation		Btu in./hr-ft^{2}-^{o}F
K	General thermal conductivity designation	12 in./ft	Btu/hr-ft-^{o}F
K_f	Thermal conductivity of a freezing material		Btu/hr-ft-^{o}F
K_i	Thermal conductivity of a frozen material		Btu/hr-ft-^{o}F
K_u	Thermal conductivity of an unfrozen material		Btu/hr-ft-^{o}F
PMR	Protected Membrane Roof		
T_{rm}	Interior building temperature		^{o}F
V	Coefficient of variation		percent
w	Water content based on dry weight		percent
$\bar{X}$	Statistical mean		
γ	Total unit weight		pcf
σ	Standard deviation		

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